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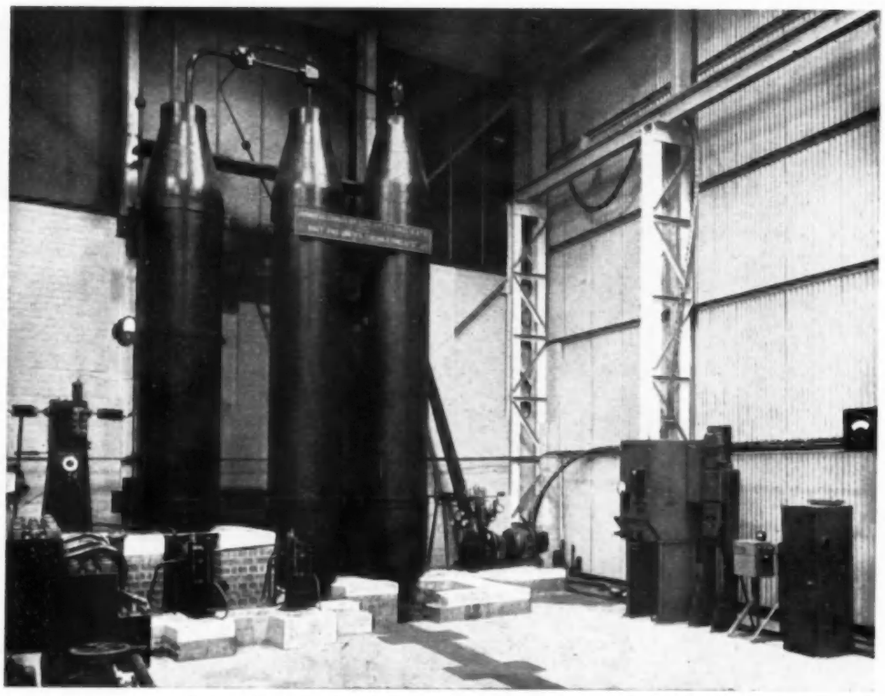

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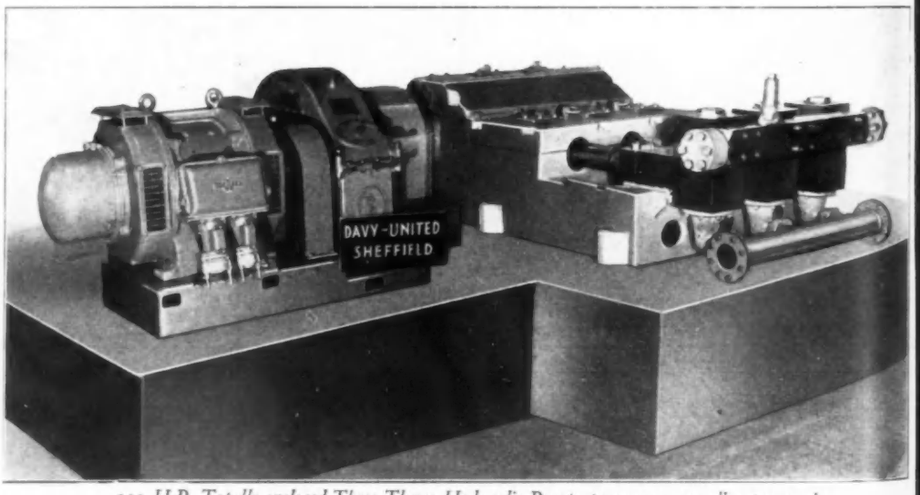

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THE CONTROL OF POWER IN LARGE INTER-CONNECTED ELECTRIC SUPPLY SYSTEMS.

By T. F. WALL, D.Sc.

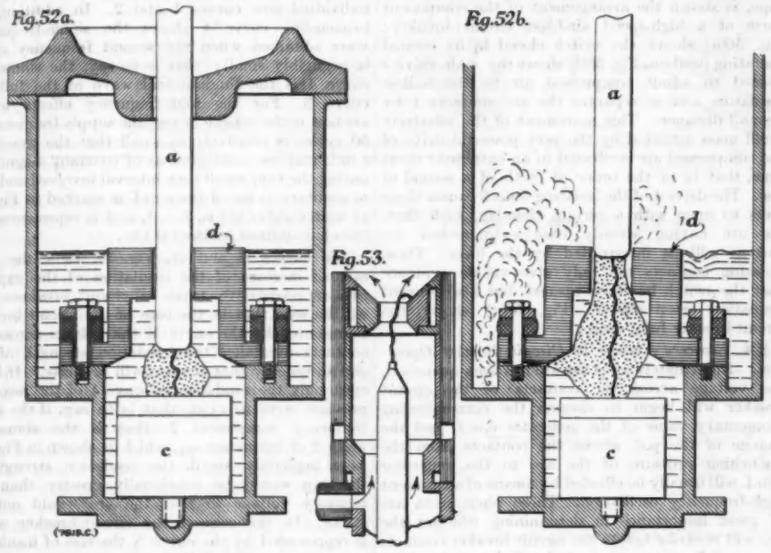
(*Continued from page* 122.)

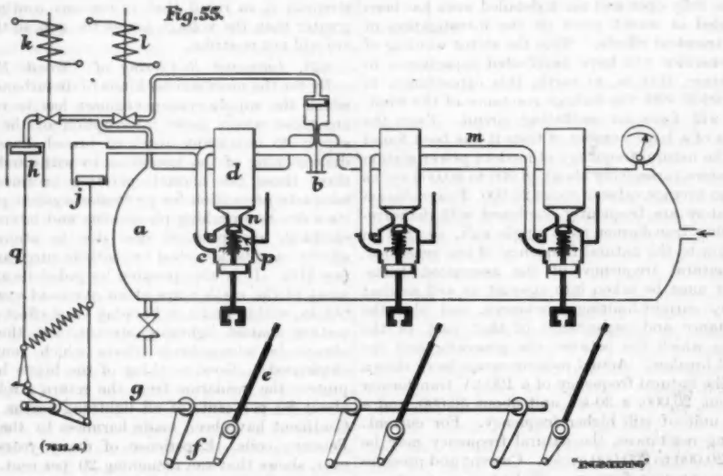
§22. *Water-Expansion Circuit Breakers.* — Although the low content oil type of circuit breaker has proved to be a great advance on the oil-tank type, it does not entirely eliminate the objections which have been raised against the use of oil for switching purposes and a great deal of research has been carried out with a view to using some other liquid of a non-inflammable type instead of normal switch oil, such for example, as some type of non-inflammable oil, or water. Investigations which have been carried out with non-inflammable qualities of oil have led to the conclusion, however, that no useful progress is likely to be made in that direction. Early investigations showed that among inorganic substances only water is possible for this purpose, other liquids such as mercury or silicon compounds having been ruled out on account of their conductivity, poisonous nature, or moisture sensitivity. The number of organic liquids that are suitable is much greater, but they are in most cases inflammable and have greatly inferior properties, together with higher costs, than the normal quality of switchgear oil.

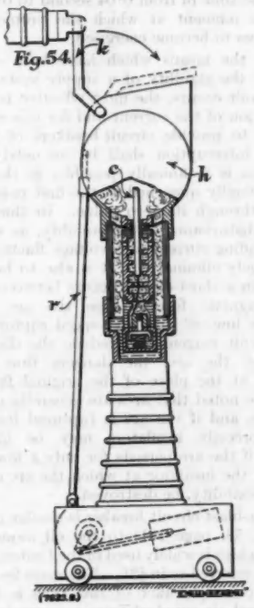
As regards water, it has been objected that this is not suitable for circuit breakers for high-tension operation. This objection is partly answered by the fact that for many years, such circuit breakers have been in operation for pressures up to 45 kV. This pressure does not, however, represent the limiting value. Experiments indicate, in fact, that there is no upper limit to the pressure for which water circuit breakers may be successfully used. Water, as well as oil, has the characteristic property of producing hydrogen gas at the high temperature of the arc and as has been pointed out already, the high heat conductivity of hydrogen is a most valuable property in producing a powerful cooling action on the arc and thus forcing it to extinction. To the conductivity of water, small as it is, may be referred the fact that, in contrast with oil, when switching off transformers, cables, or overhead lines, there is practically no excess pressure rise and this has been fully confirmed by actual experiment. Also due to the conductivity of water is the absence of pressure surges and heavy transient currents when switching on to a circuit, this being particularly the case for operating pressures up to 12 kV. These favourable characteristics of water can only be utilised on the assumption that it is possible to avoid the unfavourable characteristics, such as the high solvent power, high capillary effect, variability of conductivity, and corrosion possibilities. Practical experience over many years has shown that these disadvantages have now been completely overcome and it is claimed that up to 60 kV, water is the ideal liquid for quenching the arc in circuit breakers.

In these switches a water-base liquid commercially known as "Expansene" is used and Figs. 52(*a*) and 52(*b*) show diagrammatically the principle of operation. A quenching chamber is provided for each pole, there being only one break per pole, in contrast with the oil switch which has at least two breaks per pole. The quenching chamber is partly filled with water. The movable contact is a rod, as shown by *a*, the fixed contact being of the tulip type and is shown at *c*. As the movable contact rod leaves the tulip contact an arc is formed which generates steam. When the steam pressure reaches a sufficiently high value, the hood *d* which is held in position by means of cylindrical rubber sleeves, is forced upwards and allows the steam to escape as shown in Fig. 52(*b*). The consequent rapid expansion of the steam (hence the name "expansion switch") produces a powerful cooling effect on the arc and quenches it after a few half-cycles of the current have passed.

The general arrangement for one pole of a water type of circuit breaker is illustrated in Fig. 54, the arc-quenching chamber being shown in section.







The switch is operated by means of compressed air which is admitted to the cylinder shown in the base of the structure. The piston rod of this cylinder is coupled to the link *r*. The upper end of this link, acting through the mechanism which is housed in the circular chamber *h* at the top of the switch, withdraws the contact rod *c* from the tulip-type lower contact. The mechanism, which is controlled by the link *r*, operates to open the isolating link *k*, the control gear being such that this link opens after the arc has been quenched and consequently, no current is interrupted when the link *k* opens.

It was formerly thought that the only advantage of water over oil was that it is non-inflammable and that in all other respects it must be considered to be inferior. Practical experience over a long period, however, has shown that this view is not correct. No carbon material is present with water switches so that there is no danger of fumes being developed and there is no poisonous substance produced. The most significant fact is that when water is decomposed by an arc, the amount of gas generated per kilowatt is only about one-seventh to one-tenth of the amount generated by oil. Experience has also shown that with water as the quenching liquid, high-tension switches can be built having very small dimensions and capable of interrupting currents up to 60,000 amperes at 6 kV. It has been thought that a persistent arc might cause the hydrogen gas to burn, but actual tests have shown that this is not so. The explanation is that when hydrogen is mixed with steam it is not inflammable and is not explosive because even if ignition were to occur at one place, the immense absorption of heat which would take place in the steam mixture would prevent the ignition from extending.

§23. *The Air-Blast Circuit Breaker.*—The two essential characteristics of modern circuit breakers are absolute reliability and high-speed operation. In nearly every type of circuit breaker, the rupture

of the arc is effected by subjecting it to a flow of gas or vapour for the purpose of producing drastic cooling. As already shown in §§ 19 and 20, effective cooling will destroy the conditions for the existence of the arc, the heat will thus pass outwards to the cooling medium while within the core of the arc the quenching medium becomes dissociated into electrons and ions thus consuming immense amounts of heat. In the majority of circuit breakers, the extinguishing medium is formed and put into motion by the arc itself. This preparatory action consumes time and consequently limits the speed at which the extinction can take place. An outstanding feature of the air-blast type of circuit breaker is that the mass of the moving parts is made relatively very small, and it was the first type of switch which made it possible effectively to interrupt the current within the time of from 0·04 second to 0·05 second from the moment at which the protective relay commences to become energised.

Of all the means which have been devised to maintain the stability of a supply system when a service fault occurs, the most effective is the rapid interruption of the current and for this reason it is essential to provide circuit breakers of which the time of interruption shall be as nearly one-half a cycle as is technically possible, so that the arc shall be finally quenched at the first passage of the current through its zero value. In this way, the risks of disturbance of the stability, as well as the corresponding current and voltage fluctuations, are very largely eliminated. It is also to be observed that when a short-circuit occurs between lines, the electromagnetic forces cause the arc to travel along the line, so that high-speed rupturing of the short-circuit current will reduce the distance travelled by the arc, the dangers thus becoming localised at the place of the original fault. It is also to be noted that arcs are generally confined to insulators and if the arc is ruptured immediately, these porcelain insulators may be undamaged, whereas if the arc persists for only a few tenths of a second the insulator at which the arc occurs will, in all probability, be destroyed.

The air-blast circuit breaker is similar in principle (see Fig. 53, page 161) to the oil impulse circuit breaker which is widely used in the United States and has been referred to in §21. The main feature of the modern circuit breaker of this type is the use of compressed air supplied from a reservoir at a suitable pressure. Experience with a large number of air-blast circuit breakers now in service has shown that the use of compressed air up to 16 atmospheres can be relied upon without any trouble arising from the compressed-air plant. Such circuit breakers are now available for all standard voltages from 3 kV to 220 kV and it is claimed that at the present time no other type of circuit breaker exists that can be employed in the same form throughout the whole series and for the whole range of line voltages. It is of interest to note that an important feature of the use of the rod type of contact for this circuit breaker, as shown in Fig. 53, is that no electromagnetic forces will be developed which will tend to interfere with the operation of the contacts.

In Fig. 55 is shown diagrammatically, the operating system of such a high-speed air-blast circuit breaker. In order to open the circuit, the solenoid *l* operates a valve, which admits compressed air from the reserviur *a* to the piston which opens the valve *b*. This allows compressed air to enter the distribution pipe line *m* and so to the arcing-chambers *c*. Each of these chambers contains a fixed contact *n* and a movable contact *p*, the movable contact being normally kept pressed against the fixed contact *n* by means of a spring. When the compressed air enters the chamber *c* the movable contact is forced downwards by a small amount and consequently an arc is formed between the two contacts *p* and *n*. Through the annular space thus formed, an air-blast is driven and, enveloping the arc, extinguishes it in an extremely short time. While the arc is being extinguished in this way, compressed air is admitted to the cylinder *j* and the piston, acting through the shaft *g* and the links *f*, causes the isolating links *e* to open, the sequence being such that these links open after the arc has become extinguished so that no current has to be interrupted by these links. The closing of the circuit breaker is initiated by the solenoid *k*, which opens the valve to admit compressed air to the cylinder *h*. The piston of this cylinder moves the isolating contacts through the link *q* by means of the shaft *g* and the links *f*, causing them to close the circuit with great rapidity and the closing of the circuit breaker contacts always takes place in air at atmospheric pressure.

The air-blast required to rupture the arc causes the pressure in the air reservoir *a* to fall to about one-half its original value but since the reservoir is continuously connected to a compressed-air supply system, the pressure is re-established in readiness for the next operation. In Fig. 55 the heavily lined system shows the current-carrying parts of the equipment. In Fig. 56, on the opposite page, is shown the arrangement of the component parts of a high-speed air-blast circuit breaker; Fig. 56(*a*) shows the switch closed in its normal operating position, Fig. 56(*b*) shows the main valve 3 opened to admit compressed air to the hollow insulators and so separate the arc contacts 1 by a small distance. This movement of the relatively small mass actuated by the very powerful drive of the compressed air is effected in an extremely short time, that is, of the order of $\frac{1}{100}$th of a second or less. The drive 4 of the isolating links 2 causes these links to open with a certain time-lag, such that, the arc having already been extinguished, no current will be interrupted by the links. These isolating contacts not only give visible evidence that the switch has been opened, but also prevent insulation creep effects. Fig. 56(*c*) shows the circuit breaker fully open.

§24. *Recovery Voltage in Circuit Breaker Operation.*—Immediately after the arc has been quenched, the voltage across the contacts of the circuit breaker will begin to assume the corresponding momentary value of the generator e.m.f. and the change of the p.d. across the contacts from the quenching pressure of the arc to the generator e.m.f. will usually be effected by means of a transient high-frequency oscillation. These phenomena are of great importance in determining whether the arc will re-strike before the circuit breaker contacts become fully open and much detailed work has been expended in recent years on the investigation of these transient effects. Since the stator winding of the generator will have distributed capacitance to the frame, that is, to earth, this capacitance, in association with the leakage reactance of the windings, will form an oscillating circuit. From the results of a large number of tests it has been found that the natural frequency of modern power station generators varies from about 18,000 to 40,000 cycles with an average value of about 20,000. Power station generators are frequently combined with the corresponding transformer as a single unit, so that in addition to the natural frequency of the generator, the natural frequency of the associated transformer must be taken into account as well as that of any current-limiting reactances, and also the inductance and capacitance of that part of the system which lies between the generator and the circuit breaker. Actual measurements have shown that the natural frequency of a 100-kV transformer is about 20,000, a 30-kV unit about 30,000, and a 6-kV unit of still higher frequency. For current-limiting reactances, the natural frequency may be from 20,000 to 200,000 cycles. Current and pressure instrument transformers will have a capacitance of the order of 100×10^{-12} farad, and the capacitance of the naked conductor in series may be of the order of 30×10^{-12} farad per metre.

The circuit shown in Fig. 57, which indicates a single-phase generator with current-limiting reactance in series, may be taken to be representative of a wide range of practical cases illustrative of a double frequency circuit. The solution of the equation for this system has been worked out by Kümmel, and the results show that both frequencies become prominent only when the inductances L_1 and L_2 are approximately equal. Further, it is shown that the ratio of these two frequencies will be covered by a range of values from about 1 : 2 to 1 : 4. If the ratio $\frac{\omega_2}{\omega_1}$ is less than 2, the two frequencies will give a resultant oscillation which will be approximately of sinusoidal form. If the ratio $\frac{\omega_2}{\omega_1}$ is greater than 4, one frequency will be of such relatively large amplitude that the other frequency becomes negligibly small. Similarly, if the amplitude of one frequency is less than 10 per cent. of the amplitude of the resultant wave, that frequency will have a negligibly small effect on the phenomenon under consideration.

In Fig. 58 are shown the two individual frequencies for the condition that

$$\frac{L_2}{L_1} = 1\,; \quad \frac{\omega_2}{\omega_1} = 3{\cdot}5\,; \quad \frac{C_2}{C_1} = 0{\cdot}1\,; \quad \frac{A_2}{A_1} = \frac{40}{60}.$$

The sine waves 1 and 2, respectively, refer to the corresponding frequencies ω_1 and ω_2 while the heavy-line curve 3 shows the resultant of the two individual sine curves 1 and 2. In addition, the broken-line curve 4 shows the single-frequency wave obtained when the second frequency effect is negligibly small; that is to say, the sinusoidal curve 4 is the fundamental wave of the full-line curve 3. For the high-frequency effects which are now under consideration, the supply frequency of 50 cycles is relatively so small that the generator e.m.f. may be considered as of constant magnitude during the very small time interval involved and this momentary value of the e.m.f. is marked in Fig. 58 as unit value, that is, $e = 1$, and is represented by the chain-dotted horizontal line.

The curves M and N, Fig. 59, show the time rate of increase of the insulation of the gap for two representative types of circuit breakers. It will be seen that in the case of the circuit breaker represented by the curve M the voltage across the contacts overtakes the insulation strength of the gap so quickly that the arc will re-strike. If however, only the fundamental wave 4 of the recovery pressure were to exist, that is to say, if the high-frequency component 2, that is the sinusoidal wave 2 of frequency ω_2, which is shown in Fig. 58, were negligibly small, the insulation strength of the gap would be continually greater than the recovery voltage so that the arc would not re-strike. In the case of the circuit breaker which is represented by the curve N the rise of insulation strength is so rapid that it remains continuously greater than the voltage across the gap, so that the arc will not re-strike.

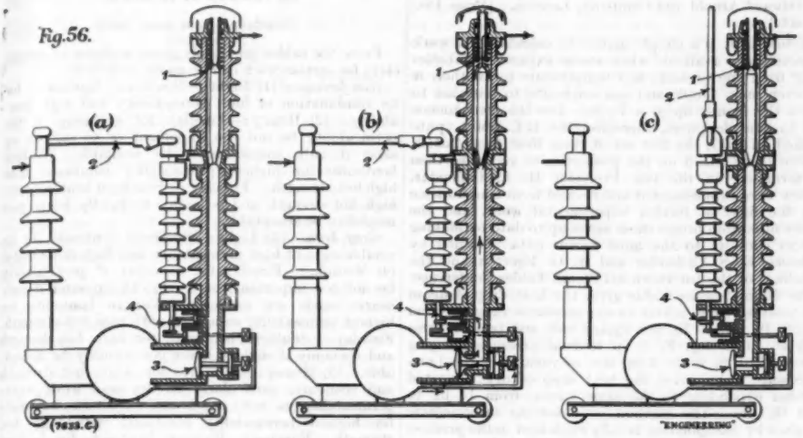
§25. *Automatic Re-Closing of Circuit Breakers*—By far the most serious kinds of disturbance with which the supply-system engineer has to contend are those which cause interruption of the power supply to important overhead branch lines. The dimensioning of the insulation to withstand about three times the normal operating pressure is an adequate precaution for protection against pressure rises due to switching phenomena and intermittent earthing, and pressure rises due to atmospheric effects may be absorbed by suitable surge arresters (see §10). It is also possible by judicious arrangement of the earth wires of an overhead system to obtain, within limits, a Faraday Cage effect as protection against lightning strokes, but there will always be atmospheric effects which cannot be eliminated.* Good earthing of the masts helps to protect the insulation from the return stroke, and about 80 per cent. of all lightning earths on the Continent have been made harmless by the use of Petersen coils. Experience of many years, however, shows that the remaining 20 per cent. sparkovers on the lines are either double short-circuits to earth or three-pole short-circuits and these make it essential to interrupt the supply immediately, if the lines are not to be destroyed.

Interruption of the supply may result in heavy financial loss within a few minutes when special processes, such as the electrolytic production of aluminium, are being operated, and for this reason the greatest possible attention has been given to methods for eliminating such interruptions. Experience has shown that an automatic and rapid re-closing of the circuit breaker is a considerable advance in this direction. For the utilisation of this method it is essential that a short rupturing time shall be possible, as is now obtainable with such modern ultra high-speed circuit breakers

* See ENGINEERING, vol. 149, page 608 (1940).

POWER CONTROL IN ELECTRIC SUPPLY SYSTEMS.

Fig.56.



as the oil-impulse and the air-blast types. Statistical records have been compiled relative to the distribution of the causes of the interruptions of the supply for the Swiss systems operating at 50 kV and 80 kV, respectively. These records are in good agreement with similar data collected in America and South Africa on systems operating at 132 kV. From these investigations, the important fact has been disclosed that only about 7 per cent. of all such disturbances are of a permanent character, the remainder being classified as follows: 21 per cent. were two-pole and three-pole short-circuits, and 72 per cent. were earths.

In America, it is customary to earth the neutral of the system permanently, so that every earth becomes a short-circuit, which means that the circuit breaker will be tripped, and it is not surprising to learn that the demand for the quick re-closing of the breaker was first made in America. The problem has been solved in that country by means of oil circuit breakers. This has meant, however, expensive and rather complicated designs, especially for the drives. In Europe the "dissonance" extinguishing coil has been used with much success for the protection against earths, and for this reason the field of application for which quick re-closing is desirable is correspondingly restricted. To reduce service interruptions, however, the new method should be given consideration even when extinguishing coils are used, because 75 per cent. of all short circuits are of only a momentary character.

When considering the development of circuit breakers provided with rapid re-closing devices, two main questions arise, viz., (i) how soon may re-closing be effected without danger of setting up a second short circuit? (ii) has any disturbance to the stability of the line been caused by the interruption and the re-establishment of the power supply? The answer to the first question involves the time which is necessary to de-ionise the paths of the short circuit on overhead lines, and this time interval is of a quite different order of magnitude from the time of de-ionisation in the circuit breaker itself because of the strong flow of cooling air which will appear in the path of the arc on an overhead line. Experimental data relative to these questions have been obtained by Brown, Boveri and Company, who found that, for the case of operating pressures of 10 kV, and for the worst conditions, the de-ionisation time is about 0·1 second. This time increases with the voltage and attains a magnitude of about 0·2 second to 0·25 second for 150 kV. At low voltages the short-circuit current hardly affects the de-ionising time, while for high voltages the time increases very considerably with the strength of the current. It has also been found that for the case of the 1,500-kW set which was used for these investigations, if the time between the interruption and the re-closing is 0·25 second, then even under the most unfavourable transmission conditions, such as when the generator is under-excited and the turbine valve fully open, parallel operation was always taken up again without further disturbance. In order to ensure that the equalising currents which will develop when re-closing shall be reduced to a minimum, the total time between the initiation of the short circuit and the re-closing of the circuit breaker shall be as short as possible; since the time necessary for de-ionising the path of the arc on an overhead line cannot be artificially influenced, it is all the more important that the time necessary to trip the relays and the circuit breakers shall be as short as possible.

Fig.57.

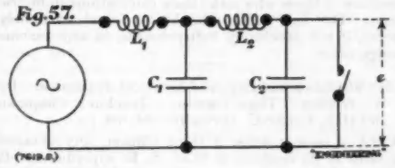


Fig.60.

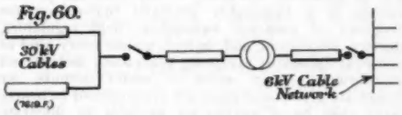
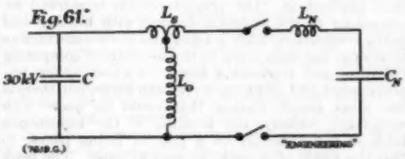


Fig.61.



In systems with earthed neutrals, the number of single-pole short-circuits is very large in comparison with the number of two-pole and three-pole short-circuits. In order to eliminate a single-pole disturbance, however, it is sufficient for one pole only, of the circuit breaker to function. The system may then remain in circuit through two lines and this will delay the generators from falling out of step with one another and will considerably reduce the strength of the equalising currents which will flow when the circuit breaker is re-closed. When closing on one pole, the de-ionising time of the affected overhead line is increased by capacitance effects in the phases which have not been cut out. This delay of de-ionisation, however, is not serious, since the tests show that re-closing even after 0·7 second after interruption of a single pole can be safely carried out. For the practical success of a rapid re-closing operation it is essential that the two circuit breakers at the respective ends of the transmission line shall trip simultaneously.

§26. *Effect of Natural Frequency of a System on the Operation of the Circuit Breakers.*—An interesting example of the effect on the operation of circuit breakers as produced by the natural frequencies of a system comprising a generator, a transformer, and an underground cable is given by a certain large urban 30-kV network. The current for this network is supplied through large transformers to 6-kV distribution sections and in one place to a 3-kV section. Each transformer is fed from two different power station groups. The transformers of a step-down station feed, in common, a medium pressure network so that they are connected in parallel through relatively low network impedances. According to requirements, the transformers are switched out or in circuit, and this occurs when the loading is approximately 40 per cent. and 60 per cent., respectively. Although, formerly, occasional difficulties arose on switching in, the switching off gave rise to no objectionable phenomena. It was, therefore, a surprising experience to find that when one of the transformers was being switched off, sparking across took place between the circuit breaker and the transformer on the high-tension side. Similar observations were also made in two other stations. Since this particular installation had been most carefully designed so that all possible disturbances should be eliminated, this experience roused great concern and immediate steps were taken to investigate the cause of it, use being made of the strip-type of oscillograph, as well as of the cathode-ray type.

Fig.58.

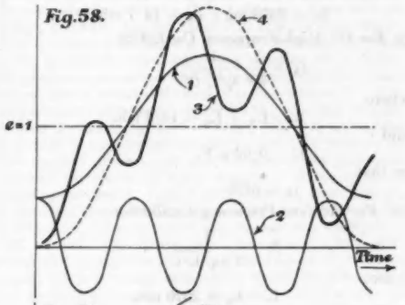
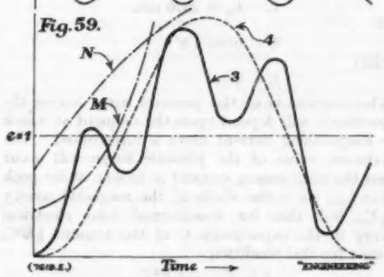


Fig.59.



In Fig. 60 is shown diagrammatically one pole of the transformer and circuit-breaker coupling between the 30-kV and 6-kV sections, and Fig. 61 shows the equivalent circuit per phase. In this circuit, L_N and C_N represent, respectively, the inductance and capacitance of the 6-kV cable network; L_s and L_o, respectively, represent the leakage and magnetising branch of the transformer, while C represents the self-capacitance of the transformer and the capacitance of the cable connection between the circuit breaker and the transformer. The conditions will now be considered under the assumption that the high-tension circuit breaker has first opened, thus cutting off the load. The transformer data are as follows:—Three-phase rating, 15 MVA; transformation ratio, 30/6 kV; leakage reactance $L_s = 7·7$ per cent.; and no-load current, $I_o = 7·1$ per cent. of the normal rated current.

If the low-tension switch now opens, the arc so formed will give rise to an oscillatory current in the circuit of C_N, L_N, L_s, C, and this will be a high-frequency oscillation, it being observed also that C_N will be so large that its reactance will be in effect zero, that is to say, for the high-frequency oscillation the capacitance C_N may be considered to form a short-circuit. When the arc is quenched, an equalising oscillatory current will flow in the circuit C, L_s, L_o and this will be a low-frequency oscillation, since the inductance L_o will be very large. The

following are the numerical values of the various constants of the circuit, viz. :—

$$C_N = 30\ \mu F : C = 0{\cdot}06\ \mu F : L_N = 1{\cdot}6 \text{ mh} : L_0 = 2570 \text{ mh} : L_2 = 14{\cdot}7 \text{ mh}.$$

(i) *For the High-Frequency Oscillation*—

$$f_h = \frac{1}{2\pi}\frac{1}{\sqrt{L{\cdot}C}}$$

where

$$L = L_N + L_2 = 16{\cdot}3 \text{ mh}.$$

and

$$C = 0{\cdot}06\ \mu F,$$

so that

$$f_h = 5150.$$

(ii) *For the Low-Frequency Oscillation*—

$$f_l = \frac{1}{2\pi\sqrt{L{\cdot}C}}$$

where

$$L = L_0 = 2570 \text{ mh}.$$

and

$$C = 0{\cdot}06\ \mu F$$

so that

$$f_l = 405.$$

The magnitude of the pressure surge across the capacitance will depend upon the moment at which the magnetising current wave is interrupted. The maximum value of the pressure surge will occur when the magnetising current is broken at its peak value I_{0m}, since the whole of the magnetic energy $\frac{1}{2}L_0 I_{0m}^2$ will then be transformed into electrical energy in the capacitance C of the amount $\frac{1}{2}E^2C$, so that for this condition

$$\tfrac{1}{2}\,L_0\,I_{0m}^2 = \tfrac{1}{2}\,E^2\,C$$

or

$$E = I_{0m}\sqrt{\frac{L_0}{C}} = \sqrt{2}\,I_0\sqrt{\frac{L_0}{C}} \text{ volts}.$$

The total three-phase magnetising volt-amperes of the transformer at the normal rated voltage will be given by the expression

$$W_0 = \sqrt{3}\,V_l I_0.$$

The voltage per phase across the transformer when unloaded will be given by the expression

$$\omega\,L_0\,I_0 = V_p = \frac{1}{\sqrt{3}}\,V_l.$$

Hence,

$$L_0 = \frac{V_l^2}{\omega\,W_0}.$$

The oscillation frequency will then be

$$f = \frac{1}{2\pi}\frac{1}{\sqrt{L_0{\cdot}C}} = \frac{1}{2\pi}\frac{\sqrt{\omega}}{V_l}\sqrt{\frac{W_0}{C}},$$

and the pressure surge will then be

$$E = \sqrt{2}\,I_0\sqrt{\frac{V_l^2}{\omega\,W_0\,C}}$$

that is

$$E = \sqrt{\frac{2}{3\pi}}\sqrt{\frac{W_0}{C}}.$$

When the constants of the circuit have the respective magnitudes already specified in the foregoing treatment, viz. :—

$$I_0 = 0{\cdot}07\ I_l = 0{\cdot}07\,\frac{W_N}{\sqrt{3}\,V_l} = \frac{0{\cdot}07 \times 15 \times 10^6}{\sqrt{3}\,V_l}$$

$$W_0 = \sqrt{3}\,I_0 \cdot V_l = 0{\cdot}07 \times 15 \times 10^6 : C = 0{\cdot}06\mu F$$

the magnitude of the surge pressure under the most unfavourable conditions will be

$$E = \sqrt{\frac{2}{3\pi}}\sqrt{\frac{W_0}{C}} = 1{\cdot}9 \times 10^6 \text{ volts},$$

and this will satisfactorily account for the sparking across which was observed between the circuit breaker and the transformer on the high-tension side when one of the transformers was switched off.

(To be continued.)

Shipbuilding in the United States.—The current *Bulletin* of the American Bureau of Shipping shows that the number of vessels under construction and/or under contract on July 1, in United States shipyards, to the classification of the Bureau, totalled 829, making together 5,462,895 gross tons. Included were 696 steamers and motorships, aggregating 5,354,450 gross tons; five Great Lakes steamers, totalling 55,500 tons; 125 tugs, barges, trawlers and similar craft, making together 52,475 tons; and three wood and composite vessels, totalling 470 tons. The corresponding figures for June 1, 1941, were 826 vessels, aggregating 5,350,070 gross tons, and for July 1, 1940, 287 vessels, totalling 1,528,260 tons.

NOTES ON NEW BOOKS.

The 1940 Heat Drop Tables. Published for the British Electrical and Allied Manufacturers' Association by Edward Arnold and Company, London. [Price 15*s.* net.]

Although it is a simple matter to calculate the work theoretically available when steam expands adiabatically from one pressure and temperature to another, it is even more simple and less conducive to mistakes to look the figures up in a Table. For the convenience of turbine designers, therefore, the B.E.A.M.A. published, in 1917, the first set of their *Heat Drop Tables*, these being based on the properties of steam as then determined by the late Professor H. L. Callendar. They were supplemented and revised from time to time in the light of further experimental work, and the present edition brings them again up to date by making them conform to the most recent data obtained by Messrs. G. S. Callendar and A. G. Egerton and the findings of the International Steam Tables Conference. The High-Pressure Table gives the heat drop of steam expanding from initial gauge pressures ranging from 3,200 lb. to 100 lb. per square inch and temperatures up to 1,000 deg. F. down to final pressures ranging from 27·0 in. to 29·5 in. Hg. of vacuum. The Low-Pressure Table gives the heat drop of dry saturated steam expanding to the same vacua, from 14 lb. to 19 lb. abs. The method of obtaining intermediate values by interpolation is fully explained in the preface, and conversion tables are also included for the convenience of those who make their calculations in metric units. The new tables should be found extremely useful, if not absolutely indispensable, in any turbine design office.

The Calculation and Design of Electrical Apparatus. By W. Wilson. Third edition. London: Chapman and Hall, Limited. [Price 10*s.* 6*d.* net.]

When a book reaches a third edition, any detailed account of its contents is likely to be superfluous. It will be sufficient, therefore, to say that the present volume is a thoroughly practical *vade-mecum* for designers of electrical switchgear, field regulators, starters, conductors, and, indeed, almost every kind of electrical apparatus excepting generators, motors and transformers. Many scores of useful formulæ for design are given, and these are accompanied in nearly every case by a worked-out example to illustrate their application. The present edition is marked by extensions to the chapters dealing with heating and heavy conductors, while a fuller and more constructive treatment has been given to the methods of computing radiation and convection losses. Various other improvements and additions have been made, but there is one other simple change that could be made with advantage, namely, the printing of the logarithmic table in the appendix on a pair of facing pages, so that the whole of it could be seen at once. The book is well known to the majority of electrical designers, and we can commend it without hesitation to the attention of the rest. Even though their knowledge of first principles may be adequate for any calculation required, memory is often treacherous, and a concise collection of rules and examples is always convenient for reference. Students should gain from it a better knowledge of the problems of practical design than is obtainable from many more elaborate treatises.

Steam-Turbine Principles and Practice. By Terrell Croft. Second edition, revised by S. A. Tucker. London: McGraw-Hill Publishing Company, Limited. [Price 21*s.*]

This book was originally written to provide operating engineers, plant superintendents and apprentices with a working knowledge of the principles and constructional details of steam turbines. The principles, of course, have not changed, but their application has undergone so many developments during the seventeen years since the volume first appeared that a complete revision of the text became necessary. The present edition, like its forerunner, appeals directly to the "practical man," who need have no more than a mechanical turn of mind and a knowledge of arithmetic sufficient to cope with a few simple formulæ to read it from cover to cover with understanding and profit. He will learn how and why a turbine develops its power, and what types of blading, nozzles, bearings, glands, couplings, gearing, governing and lubricating arrangements, etc., are commonly met with in modern machines. Chapters on operation and maintenance are in conformity with the essentially practical nature of the book, and the methods of testing and correcting the test figures to specified steam conditions are well explained. The illustrations are clear and numerous, and every chapter concludes with a number of questions by means of which the student may test his knowledge. The book is one that can be recommended to turbine operators anxious to increase their understanding of the machinery under their control.

AMERICAN SYNTHETIC SAND PRACTICE.*

By Norman J. Dunbeck.

(Concluded from page 146.)

From the tables previously given a choice of certain clays for certain work can be made, as follows:

Non-ferrous.—(1) Light:—Southern bentonite for its combination of high permeability and high flowability. (2) Heavy:—Fireclay for economy, if the permeability be not too important or to smooth up sand if only coarse sands be available. Western bentonite for highest permeability combined with high hot-strength. Fireclay:—Southern bentonite for high hot-strength and economy if slightly lower permeability be acceptable.

Grey Iron.—(3) Light:—Southern bentonite for its combination of high permeability and high flowability. (4) Medium:—Fireclay for economy if permeability be not too important, or to smooth up sand if only coarse sands are available. Western bentonite for highest permeability combined with high hot-strength. Fireclay:—Southern bentonite for high hot-strength and economy if slightly lower permeability be acceptable. (5) Heavy:—Fireclay for high hot-strength and economy, particularly on dry-sand work where permeability is not important. Western bentonite for highest permeability combined with high hot strength. Fireclay:—Western bentonite for highest hot-strength.

Malleable.—(6) Light:—Southern bentonite for its combination of high permeability, high flowability and moderate hot-strength. (7) Medium:—Fireclay for economy. Southern bentonite for highest permeability and flowability combined with moderate hot-strength to prevent cracked castings. Fireclay:—Southern bentonite for moderate permeability and moderate hot-strength. Western bentonite:—Southern bentonite for highest permeability, combined with moderate hot-strength. (8) Heavy:—Fireclay for high hot-strength and economy, particularly on dry-sand work where permeability is not important. Western bentonite for highest permeability, combined with high hot-strength. Fireclay:—Western bentonite for highest hot-strength.

Steel.—(9) Light: Southern bentonite plus cereal binder for its combination of high permeability and high flowability. (10) Medium:—Southern bentonite, Western bentonite plus cereal binder for high permeability, high dry-strength and moderate hot-strength. (11) Heavy:—Fireclay plus cereal binder for high dry-strength, high hot-strength, and high sintering point. Western bentonite plus cereal binder for high dry-strength, high hot-strength, and highest permeability. Fireclay:—Western bentonite plus cereal binder for high dry-strength and highest hot-strength.

Several methods may be used to add bonding clays to foundry sand. A small amount of clay bond may be placed on each mould before it is shaken out. With most bonds, this is satisfactory on heaps where a sand-cutter is used for sand preparation only if the cutting and mixing is done most thoroughly. It also may be spread over a heap and cut in, but full efficiency is not obtained from the bonding material in such usage, and there is danger of clay balls forming. When this method is used, the clay and heap sand should be cut thoroughly dry before tempering water is added. Fireclay and illite must be used in considerable quantity when mixed by sand cutter instead of muller, and there is a tendency for clay balls to form. Western bentonite mixes reluctantly, because of its swelling nature on contact with water. Non-swelling Southern bentonite quickly slakes into a slurry on contact with water, and is a safe material for this type of application. This has some importance in that it makes the advantages of synthetic sand available to foundries that have not felt they could use bond clay because they do not have intensive mixers.

Some foundries mix the clay bond with water to form a slurry, and use this mixture as their tempering water. This gives high efficiency from the amount of clay so used, but it is not possible to introduce enough clay for very high strengths by this method because of the relatively small amount of tempering water usually required. The method is economical, since it eliminates transportation and mixing costs as compared with machine mixing. The strength delivered depends not only upon the strength of the clay used, but also upon the quality which it is possible to carry in slurry form. This, in turn, depends upon the maximum viscosity of slurry which can be pumped. Such point of maximum viscosity for average conditions is given in Table VII, opposite. Because Western

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* Paper contributed from the American Foundrymen's Association to the 38th annual conference of the Institute of British Foundrymen, held in Manchester on July 12, 1941. Abridged.

bentonite immediately swells to a gel, only a relatively small amount can be incorporated in a slurry of pumpable viscosity. Southern bentonite, being non-swelling, readily slakes in water in the same manner as

TABLE VII.—*Clay Content and Relative Strengths in Slurries.*

——	Per Cent. Clay in Slurry.	Percentage Relative Effective Strength.
Western bentonite ..	8·25	100
Southern bentonite ..	34·20	491
Ohio fireclay	52·30	288

does fireclay. The figures for "relative effective strength" are arrived at by using Western bentonite as a base at 100 per cent., and computing other strengths from known relative values and amounts present in slurry.

The best method of re-bonding a heap of sand, where a muller mixer is available, is to manufacture a synthetic sand. This may be a mixture, in any proportions, of used moulding sand, burned core sand or new silica sand, with the proper amount of clay bond. Such a sand may be made with high or low permeability and with high or low strength, thus giving a very flexible control of sand conditions. Such a sand often is made by a night shift on the mixer, so as not to interfere with the day-time production of core sand or facing sand. When the proper sand has been prepared, it is added to heaps or systems exactly as is natural moulding sand, thus avoiding any change in sand-handling methods. When there is sufficient or excess volume of sand in the system or heap, a concentrated mixture of sand and clay bond may be made. This may vary from 20 per cent. to 40 per cent. bond. Such mixtures must be mixed very dry, usually with 2 per cent. of water or less. These mixtures reduce handling costs and aid in controlling the volume of the sand. Less efficiency is given by the amount of clay in such concentrated mixtures than is given when smaller amounts of clay are mulled thoroughly at their proper moisture content.

The statement is still sometimes made that the use of clay bonds results in loading up a heap with clay having reduced permeability. This might be true if clay were added continuously to the same mass of sand. Actually, the sand is constantly changing. Each day a portion of it is carried away on the castings, and an equal volume of prepared sand is added. A cycle is thus established where permeability is maintained at any desired point by varying the composition of the added sand. Synthetic sand is so flexible that it makes sand control easier. The purpose of sand control is to permit the prediction of the results to be obtained through proper selection and testing of materials. If bad castings result, the fault is with the sand control and not with the sand, whether naturally-bonded or synthetic.

It is a simple matter to add clay bond to any sand-handling system if the system has any type of sand mixer. Any type of clay will work successfully, because the clay is added in small regular amounts. The clay may be placed on top of each mould before it reaches the shake-out; it may be added manually or by any type of feeder at the shake-out; it may be fed into the system in any convenient manner as a prepared synthetic sand of any desired strength. Burned core sand which is shaken out into the system sand usually aids in maintaining the necessary volume of sand. If additional silica sand be required either for volume or permeability, it may be added in any convenient manner.

Bonding clays are of particular value in preparing facing sands, since they permit great flexibility in the control of strength without the notable variations in permeability which would accompany similar changes in strength if effected by additions of naturally-bonded sands. The usual facing mixture consists of used moulding sand, plus some casting-cleaning element (such as coal dust for iron castings), plus clay bond, plus enough silica sand to give the required permeability. Burned core sand from oil-sand cores may replace the silica sand if its grain size be such as to ensure the necessary permeability. Since such silica or core sand is the only new sand material entering the foundry, it eventually will dominate the heap or system sand which comes back to the mixer to be made into facing or synthetic sand. As the permeability of this returned sand rises, the amount of burned core sand or new silica sand being added to the facing mixture is decreased. In foundries where it is essential to produce a very fine finish, a fine silica sand is used. In any case, the object is to secure a sand of maximum fineness which will give the permeability required through its uniformity.

When a durable clay is used in the facing, it loses only a moderate amount of strength on pouring, and the remaining strength, upon mixture of facing and backing sand, is frequently sufficient to maintain the strength of the backing sand without further clay additions. In many American iron foundries, some casting-cleaning element, such as coal dust, is added to all the system sand as mixed, thus, in effect, making all the sand in the system into facing sand. This eliminates the cost of the separate mixing, storage and transportation of facing sand. No difficulty is experienced in the preparation and use of such sand, except for the fact that the sand may become quite hot when re-used several times a day. In such cases it is essential to use a bond clay which does not become sticky.

Many foundries have now installed sand-preparing and reclaiming units. Such units may have a floor-level grating into which is dumped excess or used moulding sand, burned core sand, gangway sweepings and, in general, any sand that can be collected around the foundry. A magnetic separator removes metal, a coarse screen removes hard core, wedges, etc., and a suction fan removes dust and fines. Vibrating screens may be installed to classify the sand. The amount of suction applied to the system is adjustable, and a greater or lesser amount of fines is removed, depending upon permeability and finish requirements. This cleaned sand is usually stored in a bin directly over the mixer, into which it is fed as required for the production of facing sand or synthetic sand to be added to systems or heaps. Where a reclaiming unit is in use, permeability usually may be controlled by the amount of fines removed, with no additions of new silica sand.

In any application of clay bond, it is important to mix the bond and sand dry, before adding tempering water. This results in much higher efficiency from the clay, and eliminates the possibility of clay balls being formed by the addition of water to the bond before it has been distributed through the sand. There is also a growing tendency to keep some bonding clay available in all foundries, even though naturally-bonded sand is the principal material used. The bond is used to bolster up weak natural sands, to add strength to facing sands, and to build up heaps which ordinarily require excessive additions of new sand. Such a heap would be one in which large quantities of burned core sand fell into the heap upon shaking out castings or where very heavy castings burned the sand badly on each pouring. The addition of the necessary amount of new sand to restore strength would result in a large surplus, and the daily discarding of enough old sand to make room for the new material. In such cases, clay bond is used in place of new sand, or in addition to the use of a reduced quantity of new sand.

Reprint 36–26* of the American Foundrymen's Association covers very thoroughly American practice in the testing and control of synthetic as well as natural sands. The methods used are covered in the volume "Testing and Grading Foundry Sands and Clays." A few additional comments on testing seem desirable.

In testing comparative values of clays the following conditions are necessary for accurate results: (1) All materials must be carefully measured or weighed. The difference caused by careless measuring of several scoops of clay may be greater than the actual difference in strength of materials being compared. Different clays vary considerably in weight per unit. (2) All materials must be entirely dry. A difference of ½ per cent. in water content in a damp silica sand cannot be detected by observation, but may account for as much as 18 per cent. difference in results. A difference of a few per cent. in natural moisture content of a clay may cause up to 30 per cent. difference in strength. A fireclay may appear perfectly dry when containing 4 per cent. water, and a bentonite may appear dry when containing 10 per cent. water. The moisture content of clay affects strength not only through its replacement of equal quantity of bonding material, but most importantly by its reduction of rate of distribution of the clay. (3) Clays of the same type should be tested at exactly the same moisture content in the sand. The stronger sand will feel drier and may be too dry for moulding. The proper procedure is then to keep the moisture the same and reduce the amount of clay; common and incorrect procedure is to add water until both batches have the same feel. Since synthetic mixes get weaker as they get wetter, such water addition destroys the difference in strength which it was intended to measure. (4) Test specimens should be tested individually as produced to avoid the effect of rapid surface drying. (5) Since variables are unavoidable in large-scale foundry tests, the final report should average results from at least three batches or mixes. (6) A standard should be run with each test, because of the effect of atmospheric conditions.

One important fact, which is not given sufficient consideration in the interpretation of test results, is the relation between various tests. There is too much of a tendency to consider each test by itself. To illustrate this, it is proposed to consider only one property, namely, permeability, and the effect upon it of other factors. Some of these factors are:—(1) Water content. Two foundries, each reporting a permeability of 90, might be considered to be operating under similar conditions. Further investigation may show that one is using synthetic sand with 3·5 per cent. water and the other, naturally-bonded sand with 7·0 per cent. water. The venting efficiency of a sand obviously depends upon its permeability, which is a measure of its ability to promote gas escape, and its moisture content, which is the major portion of the gas to be evacuated. This simple fact is frequently overlooked. (2) Clay content affects permeability in two ways, since in increasing amounts it reduces permeability, not only because of the amount present, but also because of the increased amount of tempering water required. Some types of clays yield much higher permeability than others, even when present in equal quantity, and although the strength of one may be far higher than the strength of the second. (3) Grain size and shape affect permeability in three ways:—(*a*) Percentage of voids in sand, (*b*) percentage tempering water required, and (*c*) percentage bond clay required. (4) Amount of ramming or mould hardness affects permeability, since a hard-rammed mould will have lower permeability than one which is lightly rammed. The laboratory test specimen gives relative values, but foundrymen must think of permeability in terms of actual mould conditions. Dietert gives the following formula for determining mould permeability:—

$$\text{Mould permeability} = \frac{H \times P}{h}$$

where: H = laboratory specimen (average hardness); P = laboratory permeability (A.F.A.); h = mould hardness of mould. (5) The sectional thickness of sand in the mould affects permeability in the same manner as hard ramming. The thicker the section, the higher the permeability which is required, and the less informative the relation between laboratory permeability and mould permeability. Dietert gives the following formula for determining the reduction in permeability with increased thickness of sand:

$$\text{Venting permeability} = \frac{25\sqrt{P}}{D}$$

where: P = permeability, and D = depth of sand over pattern in inches.

Naturally-bonded sands conforming to the description of a more or less ideal sand are not available in all localities, and the carriage involved in transporting good sands may make them quite costly. In addition, the following objections are raised against some naturally-bonded sands: (1) It is costly to use a sand only until its strength is burned out and then discard it all, though the grain is still good and it lacks only bonding strength. (2) Any naturally-occurring product is subject to considerable variation, even when tested and controlled. (3) Most naturally-bonded sands have a rather complex mineral composition, and contain impurities. Naturally-bonded sands seldom approach synthetic sand in refractory value, sintering point or durability. (5) All naturally-bonded moulding sands, and particularly the finer sands, have a high percentage of silt in the portion known as "A.F.A. Clay." This silt reduces permeability and requires a high percentage of tempering water to make the sand reach proper working conditions and "feel." (6) Naturally-bonded sands are sometimes not available during the winter months.

Disadvantages of Synthetic Sands.—(1) Synthetic sands are workable over a narrower moisture range. (2) Synthetic sands dry out more rapidly than natural sands. (3) Most synthetic sands require more extensive mechanical equipment than is essential for natural sands. (4) There is more difficulty in finishing and patching synthetic sands than natural sands.

Advantages of Synthetic Sands.—(1) They make possible substantial savings. The cost of hauling used sand to a mixer is no greater than the cost of hauling it to the dump. The cost of transporting rebonded sand to the point of use is no greater than the cost of taking in an equal quantity of new naturally-bonded sand. The handling costs cancel out, therefore, and the charges against synthetic sand are the cost of the bond clay, the cost of any silica-sand additions, and the cost of mixing. (2) Synthetic sands have much greater durability or life than naturally-bonded sands, and 1 ton of synthetic sand may maintain strength for 50 per cent. to 200 per cent. longer than a ton of naturally-bonded sand. (3) Silica sands are much more uniform than naturally-bonded sands, and bonding clays are dependably uniform. (4) The fine material in the sand will be almost all active bonding clay. This results in higher permeability, better flowability, and considerably less tempering water required. (5) Synthetic sands are almost always more refractory, and give higher sintering points than naturally-bonded sands. (6) Being made from simple materials, synthetic sand is easy to control. (7) Synthetic sand eliminates the expense of winter storage of natural sand, and difficulties due to freezing in unheated bins.

* "Present Status of Foundry Sand Investigation and Control," by W. G. Reichert.

RECONDITIONING INSTRUMENT JEWELS AND PIVOTS.

In view of the present difficulty in obtaining replacement jewels and pivots for the reconditioning of electricity meters, the Meter Technical Committee, which has been formed to assist the Electricity Commissioners on technical questions arising from the operation of the Electricity Supply (Meters) Act, 1936, has reviewed the problem of utilising old jewels and pivots. This Committee has made detailed practical suggestions which are likely to prove of great value to those who are faced with the problem of maintaining meters at an accepted standard of accuracy. Although the report, which has been presented, is concerned only with electricity meters, it is likely to prove of service to those who are concerned with various other types of instruments.

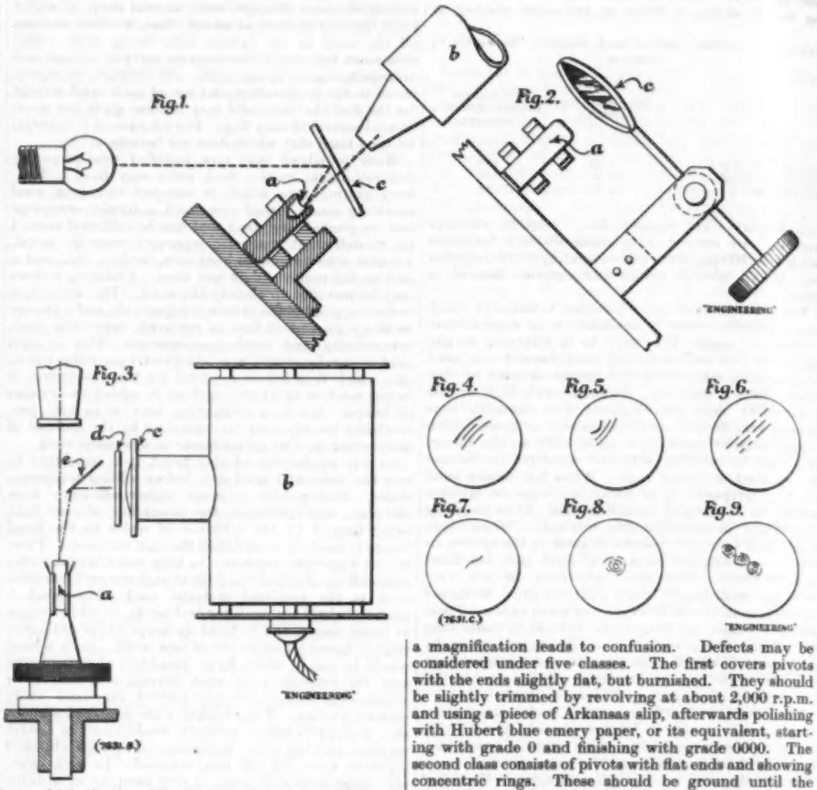
It has been found in practice that, in many cases, by suitable treatment some further years of service may be obtained from old jewels and pivots. As, however, the results obtained may not equal those given by new jewels and pivots, the report suggests that it may be necessary for electricity undertakers to take advantage of the war-time modification in the meter-testing specification which has been allowed by the Electricity Commissioners. This permits low-load performance to be taken at one tenth instead of one twentieth of full load. As the life of such reconditioned meters cannot be expected to equal that of those fitted with normal bearings, records should be kept of all instruments dealt with, so that they may be brought up to standard as soon as conditions permit. The repair of jewels and pivots is a skilled job, requiring considerable experience, and since some electricity undertakers are likely to lack the necessary facilities for carrying out the reconditioning, the Commissioners have arranged for the Area Meter Examiners to be at the disposal of electricity undertakers for the purpose of giving assistance and advice.

As the cup of an instrument jewel is of small dimensions it is necessary that any reconditioning work should be preceded by microscopic examination. The arrangements made should permit this work to be carried out quickly and should not demand the use of elaborate apparatus. The report recommends three suitable procedures. In each case, it need hardly be said, it is necessary that the jewel should be properly cleaned before examination; a serious defect may be obscured by a very slight film of grease or dust. The first arrangement recommended involves the use of a simple microscope with a magnification of from 40 diameters to 70 diameters. The stage is fitted with means for holding the jewel co-axially with the microscope and automatically positioning it with the cup in focus. In the sketches of the arrangement shown in Figs. 1 and 2, the jewel *a* is held in Vee guides so that it can be rotated and easily changed. The microscope is shown at *b*. The jewel is illuminated from a small 6-volt lamp, the light from which is reflected from the surface of a thin cover glass *c*, which is carried by a universal mounting consisting of a ball held between spring strips. By tilting the cover glass and rotating the jewel, the whole surface of the cup may be rapidly examined.

The second method recommended involves the use of a long-focus binocular microscope with a magnification of 80 diameters. The jewel is held by the fingers in its mount and is illuminated by a 60-watt pearl lamp carried in an anglepoise fitting. By focusing the image of the lamp and then closing in very slightly, the surface of the jewel shows up sharply. After short experience, the jewel can be rotated and focused by the fingers at all angles without touching the setting of the microscope. Long focus is the essence of the convenience of this method. For the third procedure a similar long-focus microscope is used, but the jewel is clipped in a holder which keeps it in focus while permitting ready rotation. The arrangement is illustrated in Fig. 3. The jewel in its spring clip is shown at *a*. Light from a 12-volt 25-watt lamp in the hood *b*, and fed by a small transformer, is focused by a condenser *c*, and ground-glass diffuser *d*, on to the jewel by means of a piece of mirror glass *e* set at nearly 45 deg. just outside the line of vision. This method of examination is stated to show up faults extremely well and to be superior to the second method.

The defects which are found in jewels consist of surface cracks, scratches and wear. Surface cracks, when in focus, appear as sharply defined lines on the surface. If there is more than one, they are parallel. They may appear straight or curved, depending on the optical axis of the jewel. Three typical examples of cracks are shown in Figs. 4, 5 and 6. Scratches, which may have been present from the original polishing, or may be due to debris or swarf impacted between the jewel and pivot during transport, differ from cracks in being less sharply defined and showing no clearly marked direction. An example is illustrated in Fig. 7. Wear will be found as a rounded area approximately in the centre of the cup, as shown in Fig. 8, when the meter

RECONDITIONING INSTRUMENT JEWELS AND PIVOTS.



from which the jewel has been taken has spent most of its life at no-load or at low loads. In meters which have run for long periods at high-load, the rounded areas may extend outwards up the side of the cup as shown in Fig. 9. This effect is due to the displacement of the rotor system at higher loads. The depth of worn areas may be judged by the sharpness of their edges, the deeper the wear the sharper its boundaries. Other defects which may be found, include mechanical damage, due to rough handling, such as fracture or abrasions.

It is suggested that, after examination, jewels should be placed in three grades. The first of these covers those available for immediate re-use with lubrication. This grade should be restricted to jewels showing only shallow central wear, or scratches outside the possible working surface. The second grade covers jewels capable of being re-surfaced and includes those with moderate central or extended wear or with slight scratches within the working-surface area. Rejections should be placed in the third grade and include jewels with major mechanical defects, surface cracks, deep central or extended wear, or deep scratches within the working-surface area. The placing of a jewel in its correct grade is a matter of experience, but it must be noted that surface-cracked jewels are useless as they stand. Minute fragments may break off from the edges of a crack and, acting as an abrasive, cause rapid destruction of the bearing.

In cases of wear, some help towards determining the grade of the jewel may be given by an examination of the jewel and pivot before and after cleaning. A very flat pivot, or the presence of a large amount of oxide, will indicate considerable wear and in such cases it is doubtful if re-surfacing of the jewel would be economical, or possible, at the present time. There is difference of opinion about the desirability of retaining jewels and pivots in pairs, one view being that it is inconvenient and unnecessary as long as the ratio of curvature is about 1 to 4. The Meter Technical Committee, however, expresses the opinion that it is desirable to keep the jewel and pivot paired if the jewel is in the first grade, and acceptable for immediate re-use, and to do the same thing with jewels of the second and third grade until a decision has been come to about the reconditioning of the jewel. Various firms which repolish jewels in normal times are still in a position to undertake this work.

In dealing with pivots, after thorough cleaning they should be examined for defects under a microscope having a magnification of about 40 diameters. Too high a magnification leads to confusion. Defects may be considered under five classes. The first covers pivots with the ends slightly flat, but burnished. They should be slightly trimmed by revolving at about 2,000 r.p.m. and using a piece of Arkansas slip, afterwards polishing with Hubert blue emery paper, or its equivalent, starting with grade 0 and finishing with grade 0000. The second class consists of pivots with flat ends and showing concentric rings. These should be ground until the concentric rings have been removed, and then polished as above. Pivots with the ends unpolished and of bad shape constitute the third class. These are dealt with by grinding to shape and polishing. In the case of pivots with pitted ends, forming the fourth class, little can be done. The pitting usually indicates unsuitable material. The fifth class covers pivots showing cracks in a highly polished surface. This also indicates unsuitable material, the high polish being obtained by extrusion of metal forming a very thin skin, which breaks away. It will usually be found that the metal below is incapable of being polished by ordinary means. The shape of a pivot should be hemispherical and in no case should the end be ground to a needle point. The use of Diamantine or similar powders is not recommended, owing to the risk of small particles being left on the pivot and acting as an abrasive.

Old oil, dirt and oxide may be removed from jewels and pivots by washing in benzine, trichlorethylene, carbon-tetrachloride or petrol. This should be followed by rinsing in commercial alcohol, not in coloured methylated spirit. Alternatively they may be boiled in an aqueous solution of sodium hydroxide, followed by quick drying and rinsing in commercial alcohol.

The Late Mr. C. Pendlebury, M.A.—The name of Mr. Charles Pendlebury, who died at Chiswick on August 18, was a familiar one to generations of schoolboys. The youngest son of the late Mr. James Pendlebury of Liverpool, he was born on July 5, 1854, and educated at Liverpool College and at St. John's College, Cambridge. He was senior mathematical master at St. Paul's School from 1877 until 1910. His celebrated text-book on arithmetic was first published in 1886, after he had been teaching the subject at St. Paul's for nine years, and was afterwards adapted for use in various parts of the Empire and translated into several Indian languages. He also wrote many other treatises on mathematics, in some cases with collaborators. Mr. Pendlebury was for long a member of the Mathematical Association, founded in 1876 as the Association for the Improvement of Geometrical Teaching, the present name being adopted in 1897. He became honorary secretary in 1886 and continued to act in this capacity until 1936. Since he relinquished teaching in 1910, Mr. Pendlebury gave much of his time to local government work, first at Fulham and subsequently at Brentford and Chiswick. He was for many years a Fellow of the Royal Astronomical Society.

THE "EDGWICK" COLD-CHAMBER DIE-CASTING MACHINE.

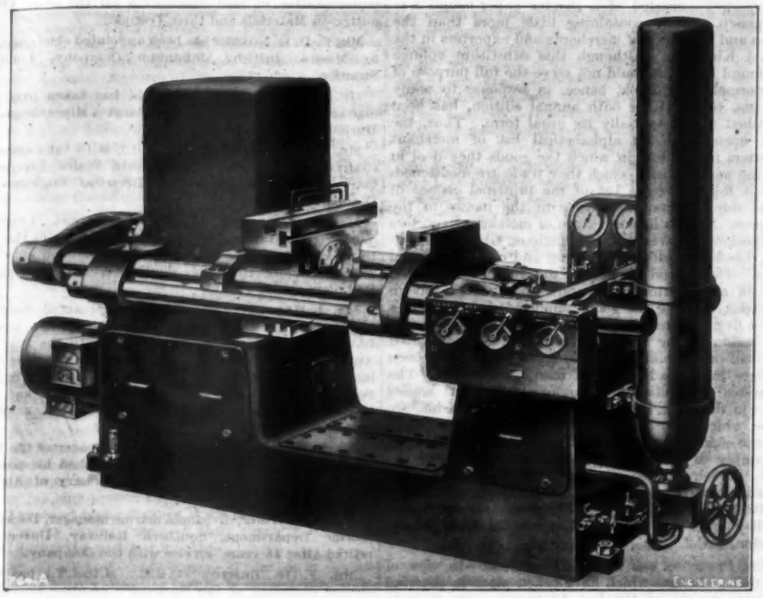


FIG. 1.

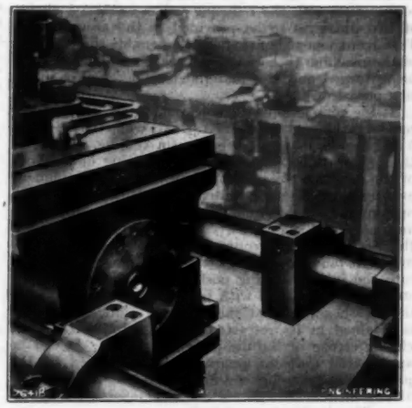
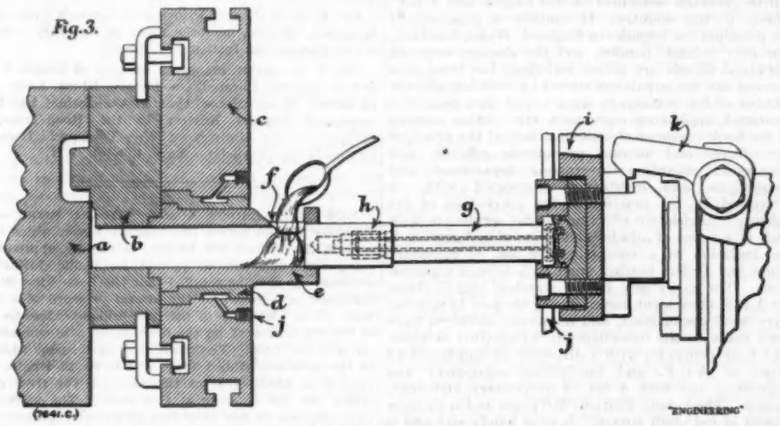


FIG. 2.



THE "EDGWICK" COLD-CHAMBER DIE-CASTING MACHINE.

THE accompanying illustrations, Figs. 1 to 3, show the latest form of the Edgwick cold-chamber die-casting machine for aluminium, brass and magnesium parts, marketed by Messrs. Alfred Herbert, Limited, Coventry. The machine, which is electro-hydraulically operated and is of British manufacture, in its standard form will inject into the die approximately 1·25 lb. of aluminium, but can be readily modified to deal with heavier or lighter castings should lower or higher injection pressures be desired. The standard plunger is 1⅛ in. in diameter. It is perhaps hardly necessary to compare in detail the cold-chamber method of die-casting with that in which the metal is melted in the machine itself and injected into the dies either by a plunger in contact with the fluid metal, or by air pressure, but it may be pointed out that in the cold-chamber machine the metal is melted in a furnace distinct from the machine, into which it is introduced by a ladle. One important advantage of this method is the elimination of the risk arising from the fact that certain metals, such as aluminium, have a tendency to pick up some of the cast iron of which the melting pot and the heated gooseneck forming the feed passage in the self-contained machine are made.

In the cold-chamber method the metal is melted in a plumbago crucible from which it is baled out. One source of contamination is thus removed, and the poured metal is in contact with the steel bushing, in which the injecting plunger works, for only about one second, since it is transferred to the die cavities immediately it is poured into the bushing and is cooled rapidly in the die. The cold-chamber method is, therefore, suitable for high-silicon aluminium-alloy pressure die-castings, since such alloys have a strong affinity for cast iron when heated in contact with it. The cold-chamber method is also suitable for die-casting brass and magnesium though, naturally, greater care has to be exercised in handling the latter metal on account of its tendency to take fire when in contact, in a heated condition, with air. The material used for that part of the plunger in contact with the fluid metal and the bushing in which the plunger reciprocates is hardened Nitralloy steel, the heat-resisting qualities of which give very satisfactory results under the severe conditions of pressure and heat.

The Edgwick cold-chamber machine is shown externally in Figs. 1 and 2, but the actual casting operation will be more clearly understood from the part section given in Fig. 3. The main elements of the machine can be identified in Fig. 1. The base forms an oil tank for the hydraulic mechanism, weirs and filters being fitted to remove air bubbles and dirt before the oil reaches the pump. The oil tank is provided with covers which are readily removable for cleaning purposes. This pump, which is of the Vickers high-pressure type, is situated in the raised portion of the base on the left, as may be inferred from the position of its driving motor visible on the left. The hydraulic cylinder for traversing the movable half of the die assembly is situated above the pump, the plunger of the cylinder carrying a crosshead to which are attached a pair of sliding rods. The movable half of the die assembly is attached to these rods, the assembly sliding on a pair of fixed guide bars. The motor is of 7½ h.p. and is push-button controlled. In the region of the hydraulic pump there is also a prefiller valve and an intensifier, the whole assembly enabling a locking pressure of 50 tons to be developed when the dies are closed. For the actual opening and closing movements a lower pressure is required and economies are, therefore, secured by a reduction in power during this period. The prefiller valve is hydraulically actuated and admits oil from a gravity tank situated above the assembly; it closes when the dies come together. Just before the dies close, their rate of movement is slowed down by means of an oil-flow restriction device in the oil feed circuit to the main cylinder. Since the traverse control is invariable, it is necessary for the total thickness of the halves of the die to be maintained at 10 in., bolster plates being employed when necessary.

The mechanism on the right in Fig. 1 consists of the injection plunger and its hydraulic operating cylinder, a control panel, pressure gauges and a nigrogen accumulator. This latter is prominent on the extreme right and is arranged so that it can be initially charged with nitrogen from a commercial bottle of the gas. The two die plates are seen in the centre of Fig. 1, the fixed plate being on the left and the moving plate on the right. Both plates, it will be seen, are formed with Tee-slots for the bolts and dogs used for securing the die blocks. The die blocks are not shown in place in Figs. 1 and 2, but are seen on the left in Fig. 3, the fixed block being indicated at *a* and the moving block at *b*, this block being attached to the moving die plate *c*. The die plate *c* is fitted with an injection sleeve *d*, having a wide groove on its external periphery through which cooling water is circulated. The injection sleeve holds the Nitralloy plunger bushing *e*. This is provided with a spigot for centring the die block and, at the other end, with a pouring slot *f*. The plunger *g* is not made wholly of Nitralloy but only that part of it, *h*, which works in the bushing. The plunger body is attached to the crosshead *i* of the operating ram by means of a spherically-mounted self-aligning coupling, as seen on the right in Fig. 3. This method of attachment prevents scoring or excessive wear on the plunger and bushing. The Nitralloy tip is water-cooled, the circulating passages being bored in the plunger body. The water connections for both the injection sleeve and the plunger are indicated at *j* in Fig. 3.

The mechanism is shown in Fig. 3, with the die blocks closed and the injection plunger retracted so that the slot in the injection sleeve is uncovered. In this position the charge of molten metal is poured into the chamber in the bushing. The injection plunger is then advanced, driving the metal into the mould. This charging stroke is more rapid than would be the case if hydraulic pressure only were used, owing to the action of the nitrogen-filled accumulator. The oil from the hydraulic pump is forced into the accumulator, compressing the gas to a higher pressure than that of the original charge. On the forward stroke, the expansion of gas accelerates the plunger movement, which is, of course, very desirable. The oil taken from the accumulator on the injection stroke is returned by the pump during the cooling time of the casting. The water circulation round the injection sleeve and through the plunger does not, of course, play any part in the cooling of the casting, its purpose being to prevent the temperature of these parts becoming too high, and also to cool the surplus metal left in the chamber rapidly so that it can be ejected in a completely solid state. There is no loss of nitrogen so

long as the machine is in continuous use, though some may occur if it is shut down for a considerable period should the valves leak. As regards the charging of the accumulator from the gas bottle, a by-pass valve, in conjunction with the reducing valve, enables a choice of two pressures to be provided in the accumulator. This arrangement is fitted so as to enable the capacity of the machine to be increased when zinc castings are being turned out, this material needing a lower injection pressure.

At the completion of an injection stroke, the plunger remains at the outer end of its stroke, while the die block *b* and the die plate *c* move to open the die, that is, to the right in Fig. 3. The metal remaining in the bore of the injection sleeve is thus pushed out, the plunger eventually projecting through the die block. The opening movement of die block and plate is continuous, and, after the slug of surplus metal has been ejected, this assembly makes contact with the crosshead of the injection plunger and pushes it and the attached ram into the initial starting position. At this point, two steel pawls *k*, engage with two hardened-steel pads on the crosshead, so that the injection plunger assembly is retained in its retracted position during the next closing stroke of the die plate and block. It will be appreciated that the pouring slot is blocked by the plunger until the dies are fully closed, as in Fig. 3, an arrangement which provides against mistakes in pouring. The die blocks in this illustration are shown diagrammatically only, as the ejector mechanism for the finished casting is omitted. This mechanism is actuated by a hydraulically-operated plunger in the centre of the fixed die plate, as seen in Fig. 2. The two blocks seen in this view clamped to the rods attached to the moving die assembly are for carrying the ejector plate when the hydraulic ejector is not being employed, as is the case when unsymmetrical castings are being made. They are adjustable along the rods, as may be inferred from their position in Fig. 1 in which they are shown behind the fixed die out of the way.

The machine is controlled from the panel seen to the right of Fig. 1. The three levers shown actuate pilot valves which control the several motions. The lever on the left effects the opening and closing of the dies, that in the centre controls the forward stroke of the injection plunger, the return stroke of which is effected by the main ram as already described. The lever on the right controls the hydraulic ejector in the fixed die. The pressure gauges visible in the background show the main pump pressure, which is the locking pressure of the machine, and the nitrogen accumulator pressure, which is the injection pressure.

PAINTWORK UNDER WAR-TIME CONDITIONS.

A CIRCULAR of considerable importance regarding paintwork under present conditions has been issued by the Ministry of Health. The circular points out that the imports of oil seeds and oils used for technical purposes are being reduced, and in consequence, in order to ensure supplies of linseed oil for other purposes the strictest economy of this material should be exercised in paintwork. It is recommended that, as far as possible, internal renovation should be delayed, external renovation should be reduced to a minimum, and alternative preservatives should be used when practicable. Substitutes for linseed oil are available in reasonable quantities for the manufacture of paint and the maximum use should be made of them. Paints made with substitutes may in some cases be stocked, and, generally, manufacturers will be able to supply them if the demand is sufficiently great. Information on the utilisation of substitute vehicles can be obtained from the Paint Research Station, Waldegrave-road, Teddington, Middlesex.

Suggestions are given in the circular as follows: For internal maintenance work, if it is possible to clean by washing down only, no repainting should be done. For external maintenance work, repainting should be delayed, but not to the point where burning off will be required. Often the repainting of sills and the bottoms of vertical members is sufficient to maintain woodwork. For new internal work, water stain is suggested, those limited areas subjected to much handling being sized and varnished in addition. Where paint is considered essential, paints of the non-linseed oil types should be used for first painting. These can be repainted at a later date with more normal paints. There should be only one finishing coat or one combined undercoat and finishing coat. Plastered surfaces should not receive decorative painting at present, but if deemed essential there are non-linseed oil paints available. As regards new external work for temporary building, the treatment of woodwork by creosote should result in adequate preservation. Coloured wood preservatives are suitable for detailed decorative treatment. For permanent new external work preference should be given to the substitute paints.

ANNUALS AND REFERENCE BOOKS.

Mercantile Year Book, 1941.—The previous edition, that for 1940, of *The Mercantile Year Book and Directory of Exporters* consisted of a slender paper-bound war emergency volume containing little more than the names and addresses of merchants and exporters in the United Kingdom. Although this substitute volume was found useful, it could not serve the full purpose of the normal Year Book, hence, in response to many requests, the 1941, or 55th annual edition, has been published in substantially its usual form. Thus, the book opens with an alphabetical list of merchant exporters in London, in which the goods they deal in and the markets with which they trade are mentioned. This is followed by a list of the principal classes of goods shipped from London with the names of the shippers. Similar lists are given of merchant exporters in Manchester, Liverpool, Birmingham, Glasgow, Bradford, Leeds, Huddersfield, Bristol and other provincial cities. The second portion of the volume is devoted to lists of importers in Empire and various foreign countries, showing the goods imported and the names of the firms' representatives in Great Britain. Events in London during the last months have complicated the task of compiling the volume, as there have been changes in the addresses of many merchants. The addresses of London and provincial merchant houses given in the book, however, so far as ascertainable, are those which were occupied on June 16, 1941. The volume contains upwards of 900 pages, and, as hitherto, a number of coloured maps of various parts of the world are included. Strongly bound in the usual brown cloth covers, the price of the book is 20*s.* net, or 20*s.* 7*d.* postage included. The publishers are Messrs. Lindley-Jones and Brother, Limited, 52, Bishopsgate, London, E.C.2.

Fire Protection and A.R.P. Year Book.—In view of the many changes which have taken place in the civil defence services in the last 12 months, the 1941-42 edition of the *Fire Protection and A.R.P. Year Book* will be generally welcomed by fire brigade and A.R.P. officers in this country. It contains a directory of the principal fire brigades in England, Wales, Scotland, Northern Ireland, London, and the Empire, and full statistical details are given, including the total area covered and the population served by each brigade, the number of fire stations in service, and data regarding personnel, appliances, equipment, etc. Other sections of the book comprise alphabetical lists of the principal fire officers and air-raid precautions officials, and information regarding Government departments and associations and institutions connected with, or interested in, the practice of fire prevention or fire fighting. Legislation affecting the fire services is dealt with in a series of articles and a useful new feature is the inclusion of a comprehensive list of Statutory Rules and Orders bearing upon civil-defence organisations. The many new British standard specifications for A.R.P. equipment, issued during the past 12 months, have been summarised, and numerous additions have been made to the miscellaneous information sections. The book concludes with a directory of supplies of all types of A.R.P. and fire-fighting equipment and requisites, and with a list of proprietary and trade names. The volume contains 310 pages and is strongly bound in red cloth covers. It is of handy size and is published, price 7*s.* 6*d.*, postage included, by Messrs. Lomax, Erskine and Company, Limited, Aldwych House, London, W.C.2.

BOOKS RECEIVED.

Fire Watcher's Log and Attendance Book. London: Herbert Fitch and Company, Limited, 31-35, Mansell-street, Aldgate, E.1. [Price 3*s.* 6*d.* net.]

United States National Bureau of Standards. Building Materials and Structures. Report BMS71. *Fire Tests of Wood- and Metal-Framed Partitions.* By S. H. INGBERG and N. D. MITCHELL. Washington: Superintendent of Documents. [Price 20 cents.]

Mathematics for Engineers. Second edition. By R. W. DULL. London: McGraw-Hill Publishing Company, Limited. [Price 35*s.*]

Elementary Engineering Thermodynamics. Second edition. By PROFESSORS V. W. YOUNG and G. A. YOUNG. London: McGraw-Hill Publishing Company, Limited. [Price 19*s.*]

Fourier Series and Boundary Value Problems. By PROFESSOR R. V. CHURCHILL. London: McGraw-Hill Publishing Company, Limited. [Price 17*s.* 6*d.*]

Elementary Structural Engineering. By PROFESSOR L. C. URQUHART and PROFESSOR C. E. O'ROURKE. London: McGraw-Hill Publishing Company, Limited. [Price 21*s.*]

Generating Stations. Economic Elements of Electrical Design. Third edition. By PROFESSOR A. H. LOVELL. London: McGraw-Hill Publishing Company, Limited. [Price 31*s.* 6*d.*]

PERSONAL.

MR. S. W. MELAOM has been re-nominated by the Council of the Institution of Electrical Engineers as representative of that Institution on the Joint Committee on Materials and their Testing.

MR. F. D. L. NOAKES has been appointed chief engineer to Messrs. British Aluminium Company, Limited, Swansea.

MR. AMOS TRELOAR, A.I.M.M., has taken over the management of the Huskiemine Barytes Mines Company, Durham.

MR. E. G. TAYLOR, B.Sc. (ENG.), is to take office as chairman of the Mersey and North Wales (Liverpool) Centre of the Institution of Electrical Engineers on October 1.

MESSRS. HOWELLS (ELECTRIC MOTORS), LIMITED, York Street, Hanley, Stoke-on-Trent, inform us that, as from August 22, the address of their London office is: 29, Winchmore Hill-road, Southgate, N.14 (Telephone PALmers Green 5428).

MR. J. HERBERT ASTON has been appointed chairman of Messrs. Tube Investments, Limited, Paddock Works, Oldbury, Worcestershire, in succession to the late MR. ARTHUR CHAMBERLAIN. He is relinquishing the appointment of joint managing director. MR. I. A. R. STEDEFORD has been appointed managing director and MR. P. G. CAREW and MR. W. HACKETT, jun., assistant managing directors.

SIR PATRICK HENNESSY, general manager of the Ford Motor Company, Limited, has relinquished his position on the Advisory Council of the Ministry of Aircraft Production.

MR. H. C. WOOD, divisional marine manager, Docks and Marine Department, Southern Railway, Dover, has retired after 48 years' service with the Company.

MR. F. G. BRISTOW, C.B.E., M.Inst.T., has been elected chairman of the National Executive Committee of the Royal Society for the Prevention of Accidents, in succession to the late SIR ALLAN HUME NICHOLL, C.B.E.

DR. R. C. WALLACE, Principal of Queen's University, Kingston, Ontario, has been made an honorary member of the Engineering Institute of Canada.

MR. F. G. SMITH, managing director of Messrs. F. G. Smith (Motors), Limited, Goodmayes, Ilford, Essex, and President of the Motor Agents' Association, has been appointed Repairs Adviser in the Road-Transport Division of the Ministry of War Transport, Berkeley Square House, Berkeley-square, London, W.1.

NEW STEEL BRIDGE ACROSS NIAGARA RIVER.—The Rainbow Bridge across the Niagara River, which is to replace the Falls View Bridge, is rapidly approaching completion and will be opened for traffic during the autumn. It may be recalled that the Falls View Bridge collapsed as a result of the lateral pressure of a huge pack of ice. The site of the new bridge is close to that of the old, and work on the foundations was commenced on May 16, 1940. The main steel arch span, which is of the hingeless ribbed type, is 950 ft. in length, and rises from abutments on the sides of the river gorge which are 200 ft. deep at this point. The main arch span consists of two steel box-girder ribs spaced 56 ft. apart. About 3,500 tons of steel are used in these ribs and an additional 2,000 tons in the superstructure and decking. The abutments are placed some 50 ft. above, and about the same distance beyond, the water line to guard against future danger from ice jams. On each bank the steel arch is joined to four concrete approach arches.

HYDRO-ELECTRIC AND STEAM POWER PLANTS IN THE UNITED STATES.—In an article, "Engineering Notes from the United States," we stated, on page 156, *ante*, that to meet defence needs for electric power, the United States Federal Power Commission has proposed to President Roosevelt the installation of hydro-electric plant having a capacity of one and one-quarter million kW in each of the years 1943 to 1946. The St. Lawrence River power project, to be carried out jointly by Canada and the United States, is included in these proposals, and it is assumed that 550,000 kW will be available from this source in 1944. In addition, the programme contemplates the installation of some 2,500,000 kW of steam plant in each of the years 1943 to 1946, mostly by private utility corporations. A tentative list of steam stations to be built under the proposed expansion programme has been published by the Commission. The upper limit of the expansion plans is based on the capacity of the manufacturers of generators and turbines. The Federal Power Commission has suggested that a federally-financed corporation should be formed to place sufficient orders for generating equipment to ensure that manufacturers operate at full capacity. It is also suggested that the standardisation of designs should be followed as much as possible in building the steam plants, in order to accelerate production.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—A highly satisfactory state of affairs exists in all branches of the local staple trades. Though control over steel supplies tends to become tighter, a good tonnage is being released for general commercial purposes, although commercial customers are hoping that a larger tonnage will be made available to enable them to increase their export trade. The raw and semi-finished steel producing branches are accounting for larger outputs. Heavy demands are being made on producers of basic and acid steels. Re-rollers are accounting for larger quantities of sheets, small bars, strip, and light sectional materials. There has been but little reduction in the demand for supplies of structural steel. Firms specialising in the production of steel props and other steel supports for underground operations in coal mines are very busy. The demand for ironworks' and steelworks' machinery and related equipment has increased considerably, and manufacturers are having some difficulty in keeping pace with orders; many of these are for rolling mills, hydraulic presses, furnaces, and all types of machinery used in engineering shops. Shipyards are requiring further supplies of forgings and castings, turbine parts, auxiliary machinery, boilers, and deck furnishings, and more business is circulating in railway rolling stock and similar products; axles, wheels, tyres, buffers and springs are all progressive lines. Trade in electrical equipment is increasing and Sheffield works are supplying record tonnages of high-class steels used in the production of generators, switchgear, transformers, and other plant. Electric power-station extensions in various parts of the country are resulting in orders for high-pressure boiler drums. The production of all types of high-efficiency steels has been augmented, some works having increased their capacity by 25 per cent. during the past few months.

South Yorkshire Coal Trade.—There is a greater demand for most classes of fuel on home account. Steelworks and ironworks are absorbing larger tonnages, and railways are building up heavy stocks of locomotive coal. Sales of slacks and smalls to electric power stations are on a large scale. The house-coal market is more active, and supplies are moving freely from collieries to merchant depots. The export position shows little change.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Keen interest is felt in the South Wales coal industry in the efforts being made to get ex-miners, who left the coalfield during the lean years, to return to the mines. An official of the South Wales Miners' Federation estimated that if the local mines were to reach the target figure in production the district would require an additional 10,000 men. Of this number, 7,500 would be required to work underground and the remainder on the surface. The district would then be in a position to produce all the coal the railways would be able to handle. Lodges of the South Wales Miners' Federation, at pits under the control of the Powell Duffryn Combine, received a report at a meeting from the lodge at the Penallta Colliery where the non-unionist position had threatened to result in a stoppage. It was stated that the lodge had nearly succeeded in its efforts to achieve a 100 per cent. membership of the Federation, and in view of this it was decided to delay the threatened stoppage. The notices to terminate contracts which had been handed in were postponed until August 30, and they would become effective on that date if the 100 per cent. membership figure was not achieved. The meeting agreed that notices should be tendered at the following collieries on the same question:—Upper Gilfach, Lewis Merthyr, Tower (Aberdare) and Abertridwr. Although the difficulty in securing supplies was holding operations in check, salesmen on the steam-coal market again experienced a keen demand from customers in the home section. In spite of the recent efforts to increase production output was still insufficient to satisfy needs and most producers could accept little fresh business for some time to come. The general tone as a consequence was very firm. Best large coals were in demand and supplies were very limited, while the sized kinds were again very scarce. The bituminous smalls continued a strong feature and were practically unobtainable for some time to come. Some of the dry steam smalls were still fairly readily obtainable for early delivery and were dull. Cokes remained busy, but patent fuel was slow.

The Iron and Steel Trade.—Activities in the iron and steel and allied trades of South Wales and Monmouthshire were steadily maintained last week. The demand was not so keen in all cases, but most works were kept well engaged in fulfilling orders already on their books.

TROLLEY OMNIBUSES AT HULL.—The Hull Corporation Transport Committee has decided to convert the Anlaby tramway route to trolley-omnibus operation. The estimated cost is 3,354*l.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The supply of iron and steel covers the actual requirements of consumers directly engaged on Government work, but leaves little surplus tonnage for general commercial needs. Buying ahead has diminished as the regulations of the control of distribution scheme have been gradually brought into smooth operation. Specifications against contracts for many descriptions of material are receiving prompt attention, but producers of most commodities have orders to execute that will keep them well employed over the delivery allocation period. The aggregate tonnage output of iron and steel is maintained at a level that enables the essential current needs to be met with the assistance of only moderate imports from overseas.

Cleveland Iron Trade.—Operations at the foundries necessitate a considerable increase in pig-iron deliveries, notwithstanding the very liberal use of scrap, and the supply is keeping pace with the growing demands. Cleveland pig is still scarce and prospects of a material improvement in the make are remote, but deliveries from the Midlands and other foundry-iron producing centres are ample for all requirements. Merchants are handling increased tonnages, but transactions are still mainly direct between producer and consumer. Official quotations of Cleveland pig remain at the equivalent of No. 3 quality at 128*s.* delivered to local buyers.

Basic Iron.—Basic furnaces are running satisfactorily and producing a tonnage which is sufficient for the heavy calls of local steelworks. Occasional small quantities are added to stocks, but there is still no Tees-side iron available for use elsewhere. The fixed price of basic iron remains at 120*s.* 6*d.*

Hematite.—In the hematite branch conditions still confine deliveries to small parcels for licensed consumers, but the stringency has been relieved to some extent by the increased substitution of refined iron and the liberal use of steel scrap wherever possible. While there is little likelihood of a material increase in production the demand is expected to diminish. Meanwhile the tonnage available for distribution is strictly rationed for essential purposes. The recognised market values remain at the level of No. 1 grade of hematite at 138*s.* 6*d.* delivered to North of England customers.

Foreign Ore.—The extensive use of local and other native ironstone, in place of foreign ore, has reduced the dependency on raw material from abroad to a level that can be conveniently met, with the exception of ores required for the production of hematite.

Blast-Furnace Coke.—Holders of Durham blast-furnace coke have large quantities for disposal, but are not pressing sales as they prefer to reduce their extensive delivery obligations before making new contracts. Local consumers are well covered and are not desirous of making further purchases. The fixed prices are based on good medium qualities at 36*s.* 9*d.*, f.o.r.

Manufactured Iron and Steel.—Ample supplies of semi-finished iron and steel are available for the re-rolling mills and deliveries of finished products to priority consumers are satisfactory. Sheets are in easy request, but makers have large orders to execute. The lull in the buying of structural steel continues. The demand for ship, bridge and tank plates is unabated and available tonnage of railway material is promptly taken up, while the pressure for larger supplies of special alloy steels necessitates a considerable increase in output.

Scrap.—Light iron and steel scrap is fairly plentiful but the large supply of mixed and heavy grades is hardly sufficient for requirements of users. Machinery metal, heavy cast iron and heavy steel are in strong demand.

MONEL NOTES.—The 24th issue of the useful little industrial journal, *Monel Notes*, has recently come to hand. This contains a summary of current procedure on the metallic-arc welding of Monel, nickel and Inconel; instructions for producing a Monel pressing, some notes on bearing materials for Monel shafts, and data on Thermo-metal. A method for rapidly distinguishing Monel and nickel from other metals is also outlined. Copies of the journal may be obtained gratis on application to Messrs. Henry Wiggin and Company, Limited, Grosvenor House, Park-lane, London, W.1.

INSTALLATIONS SECTION, INSTITUTION OF ELECTRICAL ENGINEERS.—The first meeting of the newly-formed Installations Section of the Institution of Electrical Engineers will be held on Thursday, September 18, at the headquarters of the Institution, Savoy-place, Victoria-embankment, London, W.C.2, at 6 p.m. The chairman of the Section, Mr. H. T. Young, will deliver a short inaugural address, following which a paper by Mr. R. Grierson, on "Space Heating by Means of Electrically-Warmed Floors, with Special Reference to Surface-Type Air-Raid Shelters," will be read and discussed.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, August 30, 2 p.m., Neville Hall, Newcastle-upon-Tyne, 1. General Meeting. Formal business, including the election of officers and council for the ensuing year.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, September 3, 5 p.m., The Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. General Meeting. "Smoke Deflectors for Locomotives," by Mr. H. Holcroft.

INSTITUTE OF METALS.—*London Local Section:* Thursday, September 4, 6 p.m., The Junior Institution of Engineers, 39, Victoria-street, Westminster, S.W.1. "Developments in Powder Metallurgy," by Dr. W. D. Jones.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The condition of the Scottish steel trade remains unchanged. The current output is practically all required for Government purposes. New business is not very plentiful at the moment, but the orders already in hand are sufficient to absorb the whole of the present production. Specifications from the shipbuilding industry continue to come forward regularly, but business in heavy material generally is less brisk than is the case with lighter material. This is particularly noticeable in the case of black steel sheets, the demand for the thinner qualities of which is heavy. Special steel is in strong demand. Deliveries of raw material are fairly satisfactory and the steelmakers are augmenting supplies by using considerable quantities of steel turnings. Prices are steady and are as follows:—Boiler plates, 17*l.* 12*s.* 6*d.* per ton; ship plates, 16*l.* 3*s.* per ton; sections, 15*l.* 8*s.* per ton; medium plates, ¼ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* per ton; black steel-sheets, No. 24 gauge, 22*l.* 15*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.* per ton, all for home delivery.

Malleable-Iron Trade.—The West of Scotland malleable-iron trade is rather dull, but there is still a fair amount of work on the books. Wrought-iron scrap is scarce, but local authorities are assisting materially by making collections. The re-rollers of steel bars are well placed with orders at present, but are in a position to carry out any urgent business without much delay. Good stocks of semies are held. The following are the present quotations:—Crown bars, 15*l.* 12*s.* 6*d.* per ton; No. 3 bars, 13*l.* 12*s.* 6*d.* per ton; No. 4 bars, 13*l.* 17*s.* 6*d.* per ton; and re-rolled steel bars, 17*l.* 15*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—Activity still continues in the Scottish pig-iron trade. All furnaces are operating at full capacity and the output goes quickly into consumption. Hematite iron is in great demand by the steelmakers, and the whole production is required for Government contracts. Foundry iron is moving more freely. Prices are steady and to-day's market quotations are as follows:—Hematite, 6*l.* 18*s.* 6*d.* per ton, and basic iron, 6*l.* 0*s.* 6*d.* per ton, both delivered at the steel works; foundry iron, No. 1, 6*l.* 5*s.* 6*d.* per ton; and No. 3, 6*l.* 3*s.* per ton, both on trucks at makers' yards.

INSTITUTE OF TRANSPORT EXAMINATIONS AND SERVICE MEN.—The Institute of Transport wishes to assist members, whose studies have been interrupted by calling up for service in H.M. Forces, to continue to prepare themselves for the Institute examinations. Correspondence courses are accordingly to be made available, on special terms, to members who can now devote time to reading and written work, provided that they are easily reached by post and cannot attend regular classes. On the assumption that students in the Forces will be able to devote only limited time to outside study, it is proposed that tuition should generally be restricted to one subject at a time. The fee for any one subject course will be 10*s.*, and, in addition, there will be a small fee for the loan of the necessary book or books, if required. Applications for enrolment should consist of full name (in block letters) and membership grade; rank, unit, and address for communications; subject in which a course is desired and the proposed method of paying the fee. We are informed that the Institute will make special arrangements for applicants who are receiving only their service pay. The Institute reserves the right to refuse any applicants and, at any time, to suspend the acceptance of new enrolments. Prospective students are advised to obtain the approval of their commanding officers before applying for enrolment. Applications for enrolment, or requests for further information, should be sent to the Acting Secretary, The Institute of Transport, 15, Savoy-street, London, W.C.2.

REPAIRS TO LONDON RAILWAY TUNNEL.

The certainty that a war with Germany would inevitably result in the bombing of London brought also an immediate realisation that, in an area so closely intersected by railway lines, some damage to track and to railway structures must be expected; and, from the outset, the engineering staff of the London Passenger Transport Board organised elaborate arrangements to execute emergency repairs. Dumps of selected materials were made available at key points, and repair gangs held in readiness to answer urgent calls, whether by day or night. The accompanying illustrations, Figs. 1 to 3, show various stages in the repair of an Underground tunnel, holed by a direct hit by a large high-explosive bomb during a recent raid.

The first step was to shore up the sides of the crater. Steel-sheet piles were then driven on both sides of the tunnel to a depth of several feet below rail level and supported by horizontal timber struts, to hold up the tunnel sides while the debris was removed. This stage in the repair is illustrated in Fig. 1, which shows a number of Pioneers engaged on the work of clearing the tunnel. The permanent way was then restored, and train services were resumed on week days. On Sundays, the trains were suspended to allow the engineers to work without interruption. Fig. 2 shows the two methods adopted to effect permanent repairs. Where the brick lining of the tunnel was only slightly damaged, the inner ring of brickwork was removed, and replaced by a lining of reinforced concrete. The shuttering can be seen in the foreground of this illustration.

Beyond the shuttering, the tunnel was completely wrecked and the remains of the arch had to be removed. New retaining walls were built to the requisite height and the roof was replaced by pre-cast reinforced-concrete arches, shown in Fig. 3, which were lowered into position by a crane situated on street level, which, at this point, is only a few feet above the crown of the arch.

MAGNESIUM PRODUCTION IN THE UNITED STATES.

Seeing that magnesium enters so largely into such war-time activities as aircraft manufacture, it is very satisfactory to note, from a report of the Bureau of Mines of the United States, that the industry in that country underwent great expansion in the year 1940, and that this condition is being continued by the construction of new plants and the extension of old ones. Messrs. The Dow Chemical Company, in February, 1940, doubled its producing capacity at its works at Midland, Michigan, the new production being at the rate of 13,000,000 lb. per annum. This firm's new plant at Freeport, Texas, which obtains the magnesium from sea water, commenced production in January, 1941, and it is estimated that it will produce 30,000,000 lb. of magnesium this year, while early in 1942 the annual producing capacity is expected to reach 52,500,000 lb. The chemical engineering division of Messrs. Todd-California Shipbuilding Corporation, at Permanente, California, has just started production and expects to increase its manufacturing capacity to 24,000,000 lb. or more per annum by the spring of 1942. Messrs. The American Magnesium Corporation, the largest fabricator of magnesium products in the United States, began the tripling of its manufacturing facilities in the autumn of 1940, and ordered still further expansion early this year, while other manufacturing concerns have also extended their plants, so that the annual production of 400,000,000 lb. of metallic magnesium recommended by the Office of Production Management for the national defence programme of the United States, is well on the way to realisation.

This expansion of production is a natural concomitant of increased consumption, which, it is stated in the report mentioned above, was about 75 per cent. greater in 1940 than in the previous peak year of 1939. The primary and secondary metal consumed in 1940 amounted to 11,531,000 lb. Of this, 64 per cent. was used by manufacturers of magnesium-rich alloy castings, sheets, extruded sections, etc., for the aircraft, motor-car and other industries. Makers of aluminium alloys consumed 31 per cent., a large part of which went to the aircraft industry. The remaining 5 per cent. was employed as a deoxidiser in the metallurgical industry, in zinc and other alloys, chemicals, pyrotechnics and other applications. It may be noted that of the 7,363,200 lb. used in the manufacture of structural products, 27 per cent. was lost in the manufacturing process, since magnesium oxidises readily at temperatures above the melting point. Of the structural products, 73 per cent. consisted of sand and permanent-mould castings, chiefly the former, 13 per cent. of die castings, 7 per cent. of extruded sections, 6 per cent. of sheet, and 1 per cent. of forgings and other products.

REPAIRS TO LONDON RAILWAY TUNNEL.

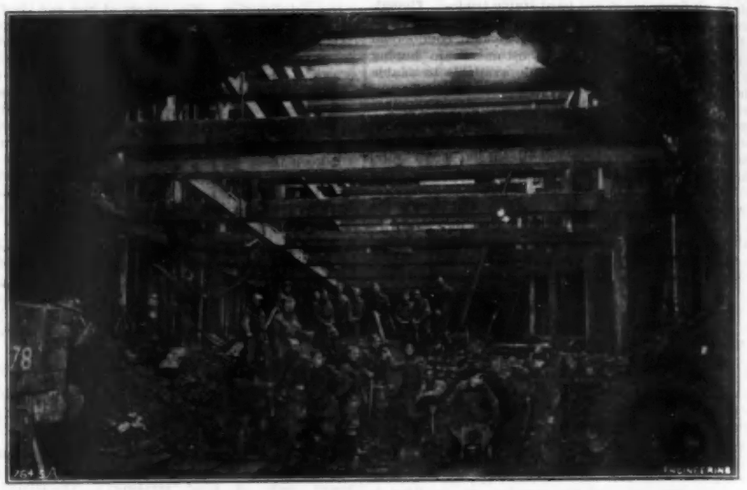


Fig. 1.

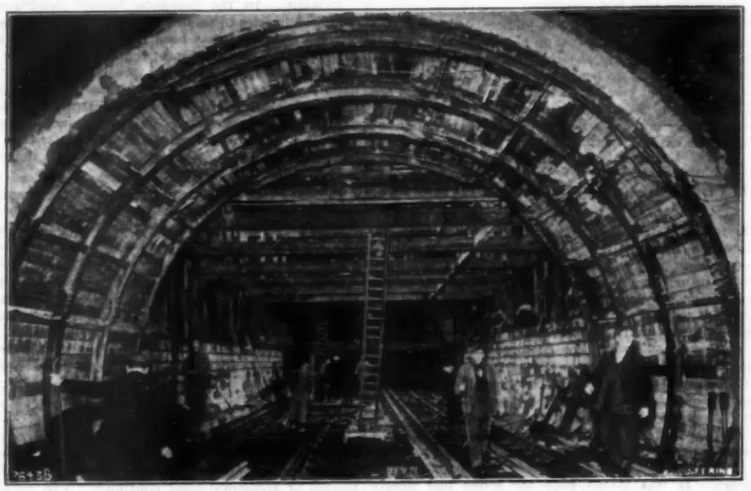


Fig. 2.

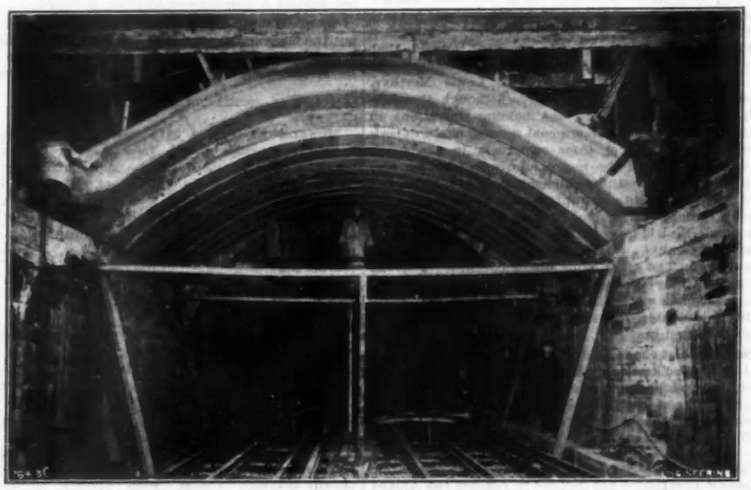


Fig. 3.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING." Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

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ENGINEERING

FRIDAY, AUGUST 29, 1941.

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RESTRICTIONS OF OUTPUT.

THE past week has seen a somewhat exceptional congestion of new Reports by the Select Committee on National Expenditure, no less than five having been published since, on the 20th of this month, there was issued a summary of the replies of various Government departments to the strictures and recommendations contained in eleven earlier reports. We may take further occasion to consider the nature of these replies. Most of them can be regarded as reasonably satisfactory, but as justifying the critical care with which the Select Committee's investigations have been carried out. Following upon this report—the 18th in the present series and the 32nd since the Committee was appointed in November, 1940—there came another, dealing with the expenditure upon an aircraft factory, which is summarised in an editorial Note on page 173. Two more reports, the 19th and 20th, respectively, dealt with the design, construction and repair of merchant ships, and the output of labour in the war industries. Lastly there has come one discussing the application of intelligence tests to Army recruits.

Throughout the long series of these most valuable surveys, the Committee have shown a notable impartiality in the direction of their criticisms. Wherever they have encountered waste or inefficiency, they have not hesitated to expose it, although the identity of those responsible has often had to be veiled in an anonymity that, no doubt, was very desirable in the national interest; since, in giving a particular delinquent a name, they could hardly avoid disclosing his local habitation. Nevertheless, it is to be regretted that they were not more precise in identifying the trade-union district delegate who is said to have distinguished himself in a certain ship-repairing centre by his restrictive activities. Without his permission, it appears, members of his union were not allowed to work overtime, and that permission was only sanctioned on condition that exceptionally high rates of wages were paid. Men who disregarded his instructions were fined by him. The same man vigorously opposed the introduction of pneumatic riveting on ship-repair work and, where it was permitted, insisted on the retention in the riveting squad of an unnecessary man who, otherwise, might have been usefully employed elsewhere. He also refused to allow the members of his union to do their share of fire-watching.

The sub-committee which carried out the actual investigation and drew up the report state that they "have grounds for believing that other trade unions—and a large proportion of the members of the particular union concerned—disapprove of the policy of the district delegate responsible," and add that "it is beyond dispute that this policy has resulted, and still results, in delaying the completion of merchant-ship repairs." They suggest that "suitable constitutional action should be taken to make it impossible for any individual to hinder the speediest possible repair of damaged merchant vessels." It was reported subsequently in *The Times* that an agreement was reached nearly a month ago, providing for the unrestricted use of pneumatic tools, and that, it is understood, the "other points of criticism were fully met in the agreement."

This may be so; but, in fairness to all those—employers, trade-unionists, non-unionists, and many more who are in none of these categories—whose utmost efforts are being expended, and whose time, labour, money and individual freedom are being willingly contributed to the common purpose, it is reasonable to ask whether the matter is now to be dropped by tacit consent, or whether any further action is to be taken against a man whose activities seem to have been so much more positively harmful than those of many suspects who have been detained under Defence Regulation 18B. The Committee appear to have encountered these practices in one district only, and do not state for how long they had persisted, but the indications are that the restrictions had been in force for some appreciable time. There have been parallel cases elsewhere, however, to some of which we have previously drawn attention. They may not be general, though their cumulative effect in retarding the completion of necessary work must be considerable; but they should not persist at all when, for more than a year, the Government have been in possession of full power to put a final stop to them.

The other recent report of the Select Committee, dealing with labour questions, is concerned with the best use of the available labour supply, and covers a wide field. Premising that, as the manpower of the country is limited and shortages of labour have been felt for some time, it is essential that the output of each individual should be increased to the maximum, they proceed to examine the reasons why, in certain cases, this maximum was not being reached. They are careful to state that the shortcomings investigated are not necessarily general, but they are led to the conclusion that the process of transition "from a peace-time economy, based upon normal incentives to production, to a war economy in which everything is directed to the expansion of military power" is taking place too slowly, and that "more vigorous and far-reaching measures are imperative."

In achieving this aim, one prime difficulty has been a lack of accurate data by which to judge what the individual's output should be. Even the records of lost time, when these are kept at all, are by no means complete, nor are they kept on a comparable basis as between one department and another; and, as a general experience, very little use is made of them. The impression received by the Committee was that, while it was impossible to give any indication of the amount of absenteeism that would be generally applicable, it had certainly increased during the war. A reason suggested to account for this is that large numbers of people are now engaged in industrial employment who either never had opportunity to acquire a sense of discipline or have been so long out of work that they have lost it. As a corrective, it is proposed that the terms of Essential Work Orders should be amended to make it clear that persistent slackness is ground for such disciplinary action as an employer is permitted to exercise, and that, in bad cases, steps might be taken to de-reserve men of military age.

Consideration was given to the possible adverse effects of high wages. Where these are the result of bad rate-fixing, the Committee state, it is undeniable that they operate to reduce output. A case is cited in which a man had hidden pieces of

completed work under his bench to conceal the fact that the piece rate was too high; and another, in which a gang rejected a suggestion to reduce the standard time for an operation, because this would have shown up the slow rate at which they had been working for the previous six months. Cuts in reasonable piece rates are indefensible, but many piece rates, initially reasonable enough on the evidence then available, become demonstrably unreasonable when they have been in operation for some time. Too often, however, any proposal to revise a piece rate downwards, in the light of experience of its operation, is regarded at once as a *casus belli* by the employee and his trade union, and the bad rate persists as the only alternative to a strike and a consequent cessation of urgent production. The Government have power to deal with this situation also, if they would exercise it and if, instead of promulgating vague warnings about the dangers of inflation, they would boldly proclaim what is in fact the essential truth, that the only sure preventive of inflation is for every man to do a little more work for the same money instead of demanding more money for the same work.

There is really nothing new in the situation. "Time and again members of the Government have announced publicly that the employers have placed themselves completely under the control of those responsible for the provision of material for the Navy and the Army. . . . All legislation, as well as departmental regulation, has been based on this concessionary spirit, and the individual rights of the employer have to conform to this patriotic and unselfish attitude. Never have the employers complained in any way about the compulsion which has been exercised in every respect, not only in the choice of work or extent of energy demanded from the staff, but also as to the extent of profit arising from such work. In sharp contrast, there seems to be on the part of organised labour a determination that they shall have a free hand . . . to enforce conditions of employment involving compliance with trade-union regulations, or to exact such terms of remuneration as they choose. . . . The workers are more numerous. We need not inquire whether they are more impressed with the duty of the citizen to the State. Expediency suggests that the line of least resistance should be taken by arbiters; the multiplicity of opponents on the workers' side wins the day. The men must be pleaded with, must be soothed, must be dealt with as fretful children. The 'face' of the leaders must be saved; compromise must follow compromise until they become masters of the situation. On the other hand, the employer must be coerced to agree to those conditions. . . . He knows that the future of the Empire depends upon unity of effort to accomplish the tremendous task imposed upon this generation. The employer thus willingly accepts compulsion, not only as regards terms of employment, but as regards the increased remuneration of the workers and a profit far below that justified either by the turnover or by the risks involved in the utilisation in future of capital now invested to achieve the immediate end in view."

Perhaps we may be pardoned this lengthy quotation in view of its appositeness to some of the features brought out by the reports of the Select Committee. It is taken from the leading article in ENGINEERING of July 23, 1915. How many millions have been spent since that date on education, we cannot say, off-hand; probably the figure approaches 1,500,000,000*l*. We do not believe that this vast expenditure has been entirely wasted, so far as the mass of the industrial population is concerned, but that it has definitely increased the capability of the average working man and woman to judge broad issues independently. There is evidence of this in the fact that there has been notably less trouble caused by irresponsible labour agitators in this war than in the last. In the fullness of time, we believe, the good sense of the rank and file may render nugatory the efforts of the small proportion of malcontents who regard it as their mission in life to promote a state of constant dissatisfaction in the hope of reaping sectional benefits. Meanwhile, it is essential that they should be effectively restrained; preferably by their wiser peers, but, if necessary, by the authority of the Government.

METAL RECTIFIERS.

THE development of the metal rectifier from a laboratory phenomenon to an appliance of practical utility within the past fifteen years or so, is a striking illustration of the value of applied research. Workers in the field of electrical engineering are placed in a relatively advantageous position, as compared with those dealing with mechanical problems, owing to the fact that the phenomena with which they are concerned are, in general, capable of accurate and usually relatively easy measurement. This condition favours rapid progress, although it does not guarantee it. It is a safe assumption that the reason why so many types of electrical machinery have an efficiency which is not approached in mechanical appliances is that the losses concerned may be to a large extent separated for purposes of measurement, and accurately computed within a few per cent. This facility with which the performance of an electrical appliance may be analysed does not necessarily mean that the underlying physical basis of its operation is fully understood, and in a paper entitled "Metal Rectifiers," read by Dr. A. L. Williams and Mr. L. E. Thompson before the Institution of Electrical Engineers on June 26, it is stated that "practice has far outrun our knowledge of the fundamental nature of the problem."

The essential characteristic of rectifiers, other than those which depend on mechanical switching arrangements, is asymmetric conduction, and the earliest publication recording this phenomenon which these authors have been able to trace is one by F. Braun in the *Ann. Phys. Pogg.* of 1874. Braun had observed that the resistance of certain metallic sulphides appeared to vary with the direction and magnitude of the current passing through them. In the same year, A. Schuster recorded in the *Phil. Mag.* that he had found a change in resistance of a simple circuit, consisting of short pieces of copper wire linked together by terminals, according to the direction in which the current passed through it. He realised that the asymmetric conduction was due to some property of the contacts. The exhibition of the same characteristic by selenium was recorded in the *Ann. Phys. Wied.*, in 1877, by W. Siemens, who was at that time studying the photo-electric properties of that element. Shortly after this it was discovered that certain electrolytic cells exhibited asymmetric conduction, and it was shown that the effect was due to some peculiarity in the surface condition of the electrodes. During the years following these fundamental observations, it was realised that asymmetry could be applied to the rectification of alternating currents and at the beginning of this century three types of contact rectifier were available—the crystal, the electrolytic cell, and the selenium cell. The former, as is well known, was much used in early radio receivers and the electrolytic rectifier found some commercial application. The selenium cell, the most promising line of development, was at first neglected.

The remarkable developments of recent years which have brought the metal rectifier into the field of heavy electrical engineering, are due to deliberate research and development, such as has now become an every-day accompaniment of electrical manufacture. Two types, the copper-oxide and the selenium rectifier, have made important progress, although there is no reason to suppose that other types of contact rectifier may not in due course reach a commercial stage. The copper-oxide rectifier appears to have developed from the work of L. O. Grondahl in the United States, who recorded in 1926 that a plate of copper on which a thin film of cuprous oxide had been formed by heat treatment exhibited marked asymmetry and could be used for the rectification of considerable currents. The selenium rectifier, as already indicated, is of earlier origin, but rather lagged behind its competitor in application on an extensive scale. Its origin may be traced to the selenium photo-electric cell described by C. T. Fritts in the *American Journal of Science* in 1883. The practical large-scale development of the copper-oxide rectifier has, in the main, been carried out in the United States and this country, parallel progress with the selenium rectifier having been made in Germany. Of recent years, however, the manufacture and application of that form has also been undertaken in this country. The extent of the progress made and the field now covered were dealt with in a paper by Mr. E. A. Richards entitled "The Characteristics and Applications of the Selenium Rectifier," which was read at the same meeting as the paper previously referred to.

Dr. Williams and Mr. Thompson point out in their paper that the expression "metal rectifier" is really hardly appropriate, but that it is now so widely accepted that it is not likely to be altered. No rectifier so far devised is wholly metallic. What the term covers is a rectifier, with a large area of contact, in which the action appears to be purely electronic and in which there are no visible signs of chemical change during operation. The copper-oxide rectifier consists of copper sheets on which a thin film of cuprous oxide has been formed by exposing them in air to a temperature of 1020 deg. C. for about 10 minutes. They are then treated by a two-stage annealing process which results in the production of a hard, bright-red layer of cuprous oxide adhering firmly to the mother metal. After forming, this is covered by a very thin layer of black cupric oxide, which is removed by chemical means. Various methods have been employed to make efficient electrical contact between the cuprous oxide and the counter-electrode which is necessary to make up the rectifier element. The surface may be treated with colloidal graphite, or covered with a soft metal by spraying, vaporising or cathode-sputtering. It has also been found possible to reduce chemically the outer surface of the layer and then reinforce it by electro-deposition of some other metal. Although after this treatment the oxide is in contact with copper on both sides, the efficiency of the rectifier is not impaired.

The selenium rectifier consists of a carrier plate, usually of nickel-plated steel or aluminium, having a thin layer of selenium on one surface. The surface of the plate is roughened to secure good adhesion. The selenium layer may be formed either by heating the plate to a temperature slightly above 217 deg. C., which is the melting point of selenium, and allowing this material to flow into place, or the selenium, in a pulverised vitreous condition, may be sprinkled evenly on the cold plate. The faced plate is then subjected to heat treatment and the layer put under a mechanical pressure of 100 kg. per square centimetre. Further heat treatment follows and the final result is a layer of β selenium, sometimes called metallic selenium, which is of low resistance. The counter-electrode is formed by metal-spraying a low melting-point alloy on to the surface of the layer. Both types of rectifier may be built up in banks, in series or parallel, to suit voltage or current conditions.

In his paper, Mr. Richards gave some interesting examples of practical applications of the selenium rectifier. One of these is the furnishing of heavy currents for electroplating baths. In one installation they are built up in 1,000-ampere units at 6 volts and are immersed in oil tanks for cooling on the lines of an oil-cooled transformer. At the other end of the voltage scale, selenium rectifiers have been used up to 80 kV to give a high-voltage discharge for the electrostatic deposition of dust from flue gases. Another interesting application is for the supply of direct current for operating the trip coils of large circuit breakers. For this work, the rectifier is usually rated on a basis of 30 seconds operation in 30 minutes. The actual time of operation is about 3 seconds, so that ten consecutive switch operations may take place without overheating the rectifier; but it is necessary to allow the rectifier to cool before the cycle can be repeated. The rectifier has also been extensively used, in place of accumulators, for starting internal-combustion engines. Mains supply units for telephone and repeater stations and automatic battery-charging plants are other fields in which the rectifier has found application. The electrical properties of both types of rectifier may be considerably modified by variations in the method of manufacture and there is no doubt that this relatively new contribution to the list of appliances available to the power engineer will continue to extend its field and adaptability.

NOTES.

DELAYS IN FACTORY CONSTRUCTION.

THE Nineteenth Report, in the present Parliamentary session, of the Select Committee on National Expenditure deals with a particularly notable case of waste of time and money on the construction of a factory for the manufacture of aeroplane accessories. The original scheme was approved by the Air Ministry (the department responsible at the time) on January 29, 1940, and provided for a factory with a total area of 90,000 sq. ft., which was estimated to cost 90,000*l*., exclusive of certain services such as water, lighting, etc. With full services, the estimate of cost was 156,824*l*. The contract for the building work was placed in February, 1940, after competitive tendering, and stipulated that the whole of the work should be completed by June 30 in that year. The factory was to be managed on behalf of the Ministry by a company already engaged on Service contracts, at an agreed fee, irrespective of profits or turnover, and the company was to bear none of the risk. By May, 1940, it was evident that the contract date for completion could not be adhered to; but, notwithstanding the delay, the Air Ministry decided that the size of the factory should be more than doubled, by adding another building of 100,000 sq. ft., thus increasing the estimated cost to 258,324*l*. The investigating sub-committee were informed, however, that rises in the cost of labour and materials would probably increase this latter figure to about 273,300*l*. Delays continued, and, in September, 1940, a resident representative of the Ministry of Aircraft Production was appointed, to accelerate the work. The plans were altered again in the following month, and it was suggested to the sub-committee that this change, and the previous one in June, had aggravated the difficulties experienced; but the sub-committee could not accept that as a sufficient reason, and doubted whether the degree of completion prophesied for July, 1941, would in fact be reached for some months after that date. Incidentally, it was decided in October, 1940, that the establishment should be operated on commercial lines and not as a "shadow" factory, as originally intended. The sub-committee, having visited the factory, came to the conclusion that it was too elaborate for the intended purpose, and recommended that departments should bear in mind, when such buildings are erected, that they may be required for a short period only. They criticise the decision to construct the factory at all in a district where sufficient labour for erection and subsequent operation was impossible to obtain, and express the view that the provision of necessary housing accommodation in the district had not received the attention that its importance demanded. They add that they have inquired regarding the extent of the expenditure on aircraft-factory construction generally and found that many schemes were still incomplete; in the cases of which they had been informed, the proportion of the work yet to be completed represented 27½ per cent. of the total estimated cost. It is suggested that each of these schemes should be closely scrutinised, as this might enable the Ministry of Aircraft Production to reconsider the wisdom or otherwise of proceeding with them. Some had been abandoned, for reasons which the sub-committee were satisfied to be sufficient; one of these factories had involved the expenditure of more than 500,000*l*.

LABOUR TROUBLES IN AMERICAN SHIPYARD.

On August 23, the strike which, for more than a fortnight, has held up the construction of warships and merchant vessels at Kearny, New Jersey, entered upon a new phase. By order of President Roosevelt, the Navy Department then took possession of the shipyard of the Federal Shipbuilding and Dry Dock Company, which is a subsidiary of the United States Steel Corporation. The control of the yard is now vested in Rear-Admiral Harold G. Bowen, superintendent of the Naval Research Laboratory and formerly Chief of the United States Navy's Bureau of Engineers. It appears that the President holds the company to blame for failing to reach an agreement with the strikers, who had demanded the dismissal of men who were in arrears with their payments to the union and insisted that a clause should be inserted in the company's agreement with the union that this would be done. This proposal had been rejected, and some days ago Mr. L. H. Korndorff, president of the Federal Company, suggested that the Navy Department should take possession of the establishment, as the United States Army had done already in the case of the aircraft factory of the North American Aviation Company, in California.

CENTRAL COUNCIL FOR WORKS AND BUILDINGS.

As an essential step in the task of co-ordinating the building and public-works contracting resources of the country, the Minister of Works and Buildings has set up a Central Council to assist him in the administration of his various powers and responsibilities. In peace time, these two industries employ a personnel of about 1,400,000. At the present time, it is stated by the Ministry, about 750,000 are engaged on the main works of war construction and building, the rest being employed by local authorities and public-utility undertakings. There are two main organisations of employers, namely, the Civil Engineering Contractors Federation, consisting of about 600 firms, and the Building Trades Federation, which has many affiliated regional associations and represents about 8,000 firms. There is also an uncertain number of smaller builders—possibly as many as 50,000—who do not belong to the latter Federation. On the men's side, there are many trade unions, all of which are represented by the National Federation of Building Trades Operatives. Other interests concerned are the various professional, technical and scientific institutions, and the merchants and manufacturers of raw materials and finished building products. Hitherto there has been no central organisation representative of all these varied interests, although discussions have been proceeding between the Minister (Lord Reith) and the Building Trades National Council with a view to expanding its scope. Under war conditions, it is considered impracticable to leave the industry to carry on by the normal procedure of supply and demand; an increasing measure of Government direction and control is considered to be essential, and it is for the purpose of applying this direction most effectively that the new Council has been formed. Membership is confined to those interests most directly concerned—employers and operatives, with a few professional and independent members. The Council will have the assistance of the higher officers of the Ministry, which will provide a close connection with the executive machinery; and the chairman, Mr. Hugh Beaver, M.Inst.C.E., is the technical administrative head of the Ministry, which will ensure that there will be proper liaison between the Council and the executive. It is emphasised in the official statement that the members of the Council were chosen by the Minister, and are not delegates of sectional interests. In addition to the chairman, they comprise Sir Ernest Simon (chairman of Messrs. Simon Carves, Limited), who is deputy chairman of the Council; Mr. H. F. Brand (president of the British Employers' Confederation, and chairman, Messrs. Charles Brand and Son, Limited); Mr. G. M. Burt (chairman, Messrs. John Mowlem and Company, Limited); Mr. Richard Coppock (president of the Building Trades National Council and general secretary of the National Federation of Building Trades Operatives); Mr. Luke Fawcett (president and acting general secretary of the Amalgamated Union of Building Trade Workers); Mr. Oswald Healing, F.S.I. (past-president of the Chartered Surveyors' Institution); Sir Clement Hindley, K.C.I.E., M.Inst.C.E. (past-president of the Institution of Civil Engineers); Mr. John Laing (chairman, Messrs. John Laing and Son, Limited); Alderman H. E. Pitt, J.P. (past-president of the National Federation of Building Trade Employers and chairman, Messrs. H. E. Pitt, Limited); Mr. Tom Pugh (secretary, Transport and General Workers' Union, Building Trade); Mr. J. W. Stephenson, J.P. (Director of Labour, Ministry of Aircraft Production and president of the National Federation of Building Trades Operatives); Mr. John I. Loudon (president of the Scottish National Building Trade Federation, and chairman, Messrs. Loudon and Inglis); and Mr. A. McTaggart, J.P. (regional secretary, Scottish Regional Council of the National Federation of Building Trades Operatives). Official members are Mr. W. Leitch, C.B. (deputy secretary); Mr. H. H. Montgomerie, O.B.E. (principal assistant secretary); Mr. T. P. Bennett, F.R.I.B.A. (Director of Works); and Major-General K. C. Appleyard, C.B.E., M.I.Mech.E. (Director of Emergency Works). The official member who is to represent the Ministry of Labour and National Service has still to be appointed. The secretary to the Council is Mr. E. J. Rimmer, B.Sc., M.Eng., A.M.Inst.C.E.

LONDON REGION SALVAGE CAMPAIGN.

It is announced by Mr. H. G. Judd, Controller of Salvage in the Ministry of Supply, that an intensive campaign for the recovery of salvage is to be undertaken in the London district from September 13 to 27, in collaboration with the various local authorities comprising the Greater London Region. Particular efforts are to be made to collect waste paper of every kind, the need for which is described as urgent. The appeal now circulated is directed especially to business firms, who are asked to reduce as far as possible their accumulations of old correspondence files, wrappings, posters and display material, etc., and to surrender "any old (but no longer valuable) records of past business, bound or loose trade papers, ledgers, directories, etc., which are often retained, but so infrequently referred to." Since the war began, more than 370,000 tons of waste paper has been collected, but the need continues, with even greater urgency. In the normal course, any such material will be collected by firms' usual waste-paper merchants or by local Councils; but, if any difficulty is experienced in arranging for collection application should be made by postcard to the local Council office. We willingly draw attention to this new campaign, as requested by the Controller, but would urge those who possess any considerable runs of "bound or loose trade papers," British or foreign, not to assume too readily that they are fit only for pulping. Air raids have damaged a number of the libraries in which sets of such periodicals have been filed for public reference, and difficulties in obtaining regular supplies, especially of foreign technical journals, have resulted in many gaps in the series. We have been appealed to on more than one occasion to assist such libraries to complete their files by passing on to them, from among the numerous periodicals received in this office, copies which they have been unable to obtain elsewhere. It is desirable, therefore, that firms proposing to dispose of such periodicals as waste paper should first ascertain whether they would not be welcomed by one or another of the public libraries or institutions, or (in the case of British publications) by the publishers themselves. There is any amount of waste paper to be had, without destroying useful material; and, incidentally, much more might be done to avoid waste, which is even better than collecting it. As a start, we propose to contribute to the salvage collection the four copies of Mr. Judd's circular which (in spite of being wrongly addressed) reached this office on the same day, each in a separate envelope.

THE LATE MR. P. RILEY.—It is with regret that we note the death of Mr. Percy Riley, which occurred at Hill Wootton, Warwickshire, on August 23. He was a member of a family whose name is linked with the earliest developments of the motor-car industry, and was a son of Mr. William Riley, who founded the Riley Cycle Company, Limited, and who, in spite of his 89 years, still takes a keen interest in current events. On leaving school, Mr. Percy Riley set himself the task of constructing a motor car, which was completed in his father's works in 1898. The engine of the car produced was fitted with a mechanically-operated inlet valve. The plant of the Riley Cycle Company, however, was not suitable for the manufacture of such vehicles on a commercial scale, and he left the firm in 1903 to start the Riley Engine Company, with the help of his brothers, Messrs. Victor and Allan Riley. In 1925, assisted by Mr. Stanley Riley, Mr. Percy Riley commenced the production of an entirely new type of small car, and this, the "Riley Nine," became very popular among motorists. Another contribution made by him to motor-car engineering was his work in connection with the detachable wire wheel, patented in 1908.

AIR CONDITIONING OF INDIAN RAILWAY COACHES.

THE descriptions of air-conditioned passenger coaches for service on Indian railways, which have occasionally been published in English technical journals,* are evidence both of the growing extent to which the subject has for some time attracted the attention of railway engineers in India, and of the large measure of technical success that has attended their efforts to provide a most welcome amenity to passengers travelling during summer and monsoon conditions of climate. Up to a point, the practical details of the systems employed have inevitably, and very sensibly, followed American ideas and experience; for, though ranges of temperature encountered in India are perhaps somewhat more extreme than those in the United States, the differences involved are of degree rather than of principle, while on such questions as optimum temperature difference between inside and outside, or effective temperature zones of maximum comfort for passengers, the merits of the statistical data accumulated by the American Society of Heating and Ventilating Engineers are widely acknowledged. Several seasonal cycles must elapse, and air-conditioning must be developed to a far wider extent than is at present the case, before the peculiar necessities associated with the climate of India, and the range of conditions imposed during single long-distance railway journeys, can be safely averaged and translated into the performance characteristics of air treatment.

Already, however, some of the Indian railways, recognising the prospect of large developments in air-conditioned passenger stock, and no doubt utilising so far as is justifiable their present operating experiences as a basis for future policy, have begun to study the subject in considerable detail. As with most commercial applications of science, the consideration falls into two branches, concerned respectively with technical measures and costs. The interconnection between them is important, inasmuch as air-conditioning must at least pay its own way by receipts from augmented or supplementary fares, and by attracting increased passenger traffic, in order to be commercially feasible; while, on the other hand, the cost of air treatment depends upon the number of physical properties of the air that are conditioned, the extent to which desirable conditions are achieved, and the technical measures adopted for these objectives. In several directions alternative principles and types of plant are available, and the development of the most suitable apparatus for Indian railway service is a matter of concern to British makers of filtering, ventilating and refrigerating machinery.

For these reasons, as well as for its thorough survey of the monetary aspects of an engineering problem, special interest attaches to a paper† by Mr. S. L. Saksena, originally read in February, 1939, before the Institution of Locomotive Engineers, Bombay, and since published in London by the Institution of Heating and Ventilating Engineers. The paper opens with a list of the physical properties of the air within an enclosure with which conditioning treatment is concerned. They comprise temperature, humidity, movement and distribution, dust, odour, chemical composition and bacteria content. The reduction of noise, strictly outside the scope of air conditioning, is a valuable amenity which, often incidental to an air-treatment scheme, can always be advantageously kept in mind by the designer. Of the other factors, primary importance is accorded to temperature and humidity, on the scores of difficulty and expense of control, and of effect upon the comfort of the occupants of a railway coach. Full recognition is given to the importance of good distribution of the ventilating supply if conditioned air is to be fully effective, but Mr. Saksena regards this factor, as well as rate of air movement and freedom from dust, germs, and noxious components, as being fairly easy of attainment by well-established means already at the disposal of ventilating engineers. So much may be implied from the rather scant attention paid to them in the paper; and while it seems likely that all aspects of the cleansing of air for human consumption have at least as much amenity value in India as elsewhere, they admittedly do not lend themselves to computation based on physical data in the same way as the temperature and quantity of a ventilating supply.

As regards the influence of temperature on comfort, Mr. Saksena emphasises the inter-connection of this factor with humidity, and makes the further point that the sensation of comfort cannot be stated or measured in absolute terms but varies among individuals according to age, sex, clothing, state of health, nature of activity and degree of acquired adaptation. Hence no single standard of comfort can be formulated to suit every need, and the practical thing to do is to suit the majority, leaving exceptional individuals to adjust themselves by appropriate clothing. In general, the sensation of bodily comfort, as regards heat, is regulated by the degree of balance between productive agencies such as digestive oxidation of food, energy expenditure, and absorption of heat from external sources; and dissipative factors such as radiation, conduction and evaporation from the body. Within limits these agencies interact, and a composite index of the sensation of heat or cold by the human body can be evolved in terms of the dissipative factors simultaneously, giving an "effective" temperature which, while strictly a measure of the cooling power of the air, is indicative of comfort within a limited range of physical properties of the air.

For Indian conditions, the author states that 72 deg. F. is considered to be the desirable temperature inside an office or building where people are engaged for several hours at a time in sedentary occupations; but for railway coaches, where passengers move in and out at all hours of the day or night, a smaller temperature difference is necessary if chill or heat stroke is to be avoided. He therefore recommends that the desirable temperature inside a railway coach should be obtained by adding to (or deducting from) 72 deg. F. one-sixth of the difference between the external dry-bulb temperature and 72 deg. F. Thus, if the outside air is at 114 deg. F., the desirable inside temperature is 79 deg. F., while if the outside temperature in winter is 48 deg. F., the inside dry-bulb temperature should be 68 deg. F. For persons acclimatised to Indian conditions, the comfort zone is about 2 deg. F. higher in effective temperature than the corresponding zone found suitable in the United States.

The human body is a good deal more tolerant of variations in humidity than in those of temperature, and relative humidities ranging from 33 per cent. to 70 per cent. are found comfortable by the majority of passengers. In general, it may be said that the most comfortable humidity tends to be less at high than at low temperatures. For a typical Indian railway-coach condition of inside temperature 79 deg. F., a relative humidity between 40 per cent. and 50 per cent. would be suitable. Usually, however, humidity control in railway practice is not attempted, beyond what is automatically secured by condensation over the elements which govern air temperature. Although this falls short of perfection in that it takes no account of the possibly wide variations in moisture input from the perspiration of the occupants of a coach, it is no doubt satisfactory enough in practice, since air conditioning is employed only on first-class stock conveying relatively few passengers per coach.

As regards the volumetric rate of ventilating air, Mr. Saksena takes account both of the space occupied and of the number of occupants, observing that the minimum hourly quantities are two air changes and 600 cub. ft. per person. Beyond 1,800 cub. ft. per person, the hourly supply affords little improvement, and 1,500 cub. ft. to 1,800 cub. ft. per hour of fresh air for each occupant are ample for the full ventilation of a smoking compartment. A maximum air speed of about 120 ft. per minute can be tolerated with comfort by persons at rest, and something less than half this rate of movement—say, 50 ft. per minute—should be aimed at in design. The functions of this fresh air supply are to supply oxygen, and to remove odours, toxic gases and vapours, body heat, moisture and heat from other sources. The last may be enumerated as follows: (1) heat content of make-up air from outside; (2) heat leakage through roofs, walls, floors and windows; (3) heat transmitted due to solar radiation; and (4) heat emitted internally by lights and electrical equipment. In tropical India, the chief function of air conditioning is cooling, and interest centres mainly round the estimation of the size and capacity of refrigerating plant necessary to produce specified conditions. Some allowance may be made for the thermal capacity of the material of the coach and the consequent time lag in the transmission of heat, and the more conservative designer will wish to ensure the attainment of comfortable inside conditions during exceptional external conditions under which high temperature and high humidity are combined. Up to a point, however, the overload capacity of the plant can be made to meet such exceptional loads as well as to serve the day-to-day purpose of rapid pre-cooling. Thus, the author considers that a refrigerator having a rated capacity of 3·5 tons of refrigeration per day will meet a maximum heat load of approximately 4 tons, which is the estimated requirement of a standard Indian State Railway coach, fully insulated except at the ends where lavatories are situated, and having an internal dry-bulb temperature of 76 deg. F. with 65 per cent. relative humidity, when the external air is at 95 deg. F. dry bulb and 60 per cent. relative humidity. With the same coach in use during winter and possibly in the northern parts of India, where the outside temperatures may be as low as 45 deg. F., a heater of about 4·75 kW rated capacity would suffice to maintain an internal air temperature of 67 deg. F.

Mr. Saksena observes that the principal types of air-cooling plant used on railway passenger coaches employ either a steam ejector (17), a mechanical compressor (43), or ice activation (40), the figures in parentheses being the percentages of use for the respective systems, revealed by a recent census in the United States of America. Auxiliary apparatus associated with the refrigerator includes the condenser and evaporator, valves and piping; while the ice-activated system requires bunkers, unit coolers, pumps and piping. In addition, the air-conditioning equipment of the coach comprises humidifiers for regulating the moisture content of the air; fans, ducts and grills for moving and distributing the ventilating supply; thermometers and thermostats for measuring and controlling temperature; and an electric power supply, which is commonly axle-driven, having generators, batteries and motors as auxiliaries. The insulation of the coach, while separate from the conditioning plant, is of immediate importance to its practical effects. For a new coach, where construction can be designed to incorporate the installation to best advantage, the plant is preferably laid out on what may be termed the central system, in which all the air is conditioned at a single point and thence distributed to the compartments through ducts. When existing coaches have to be modified, on the other hand, it will generally be found preferable to install unit-type coolers at various points. These units may with advantage be supplied with coolant from a central cooling plant.

(To be continued.)

* *E.g., Railway Gazette*, March 7, 1941, page 251; also "Diesel Railway Traction Supplement," July 7, 1939, page 110.

† "Air Conditioning of Railway Coaches," by S. L. Saksena, B.Sc., A.M.I.Loco.E., *Jl. Inst. H. and V.E.*, vol. 8, no. 96, page 432 (1941).

INSTITUTION OF FIRE ENGINEERS.—A Midland Area Branch of the Institution of Fire Engineers has recently been inaugurated. Mr. F. Winteringham, M.B.E., chief officer of the Birmingham Fire Brigade, was elected chairman, and Mr. W. J. Richardson, station officer in the Birmingham Brigade, branch secretary.

OMNIBUSES IN ARMS FACTORIES.—The first of a large fleet of 50-seater single-deck omnibuses, to be used for conveying employees from point to point in arms factories, was inspected in London by Mr. Ernest Bevin, Minister of Labour and National Service, on August 14. Hitherto, public-service vehicles hired by the Government have been employed for this purpose.

OBITUARY.

LORD STONEHAVEN OF URY.

MEMBERS of the Institution of Naval Architects in all parts of the Empire will have received with regret the news of the death of their President, Viscount Stonehaven of Ury, P.C., G.C.M.G., D.S.O., LL.D., which occurred on August 20, following a heart attack, at his Scottish residence, Ury House, Stonehaven, Kincardineshire. John Lawrence Baird was the elder son of the late Sir Alexander Baird, Bart., and was born on April 27, 1874. He was educated at Eton and Christ Church, Oxford, and entered the Diplomatic Service in 1896, his first appointment being to Vienna. In 1898 he was transferred to Cairo and in the following year was sent to Addis Ababa. He continued to serve in Abyssinia and in Egypt, and, for his services, was made a C.M.G. in 1904. Later in the same year he left Africa to take up the position of Second Secretary at Paris and two years afterwards was posted to Buenos Aires, where he remained until 1908.

On leaving the Diplomatic Service, Mr. Baird entered politics and was M.P. for the Rugby Division

Photo: Elliott and Fry.

THE LATE LORD STONEHAVEN.

of Warwickshire from January, 1910, until 1922. He was then elected for the Ayr Burghs and held this seat until raised to the peerage as Baron Stonehaven in 1925. In 1914 Mr. Baird joined the Army and served in France with the Intelligence Corps, gaining the D.S.O. in 1915. He was called home in 1916 to act as Parliamentary Member of the Air Board, and, in 1918, was made Parliamentary Under-Secretary of State for the Royal Air Force. In the following year he was appointed Under-Secretary at the Home Office, and, in 1922, was made Minister of Transport and First Commissioner of Works, retaining this position until 1924. In October, 1925, as Baron Stonehaven, G.C.M.G., he went to Australia to take up the position of Governor-General and Commander-in-Chief of the Commonwealth. During his five years' term of office he travelled extensively in Australia and New Guinea, and encouraged the development of passenger air lines. He returned to this country in 1930 and it was in 1933 that he was elected President of the Institution of Naval Architects; he was still holding this office at the time of his death. Lord Stonehaven, who had been advanced to a viscountcy in 1938, was a popular President; he was also a member of the House and of the Scholarship and Publications Committees of the Institution.

THE PRODUCTION OF AIRCRAFT ENGINES.*

By R. F. GAGG.

RAPID acceleration in the growth of the aircraft manufacturing industry resulting from the national defence programme has presented a series of new manufacturing problems such as would ordinarily be encountered only over a period of several years. The most urgent of current problems is the requirement for the feasible maximum of production. Engine output appears to be limited principally by the capacity of management and trained personnel to take the punishment imposed by the programme. When plans now under way are completed, the combined output of the American aircraft-engine industry will approximate 15 times its capacity in the summer of 1939. The basic problem of increasing production is presented with a corollary demand that there shall be no sacrifice in the technical performance and durability of the product. It is realised that even aircraft destined only for war-time combat service must be dependable in the highest practical degree. Frequent need for repair, under conditions where repairs are virtually impossible, has amply demonstrated that the most useful aeroplane is the one which can be depended upon to perform its mission repeatedly under difficult operating conditions, far from adequate service facilities. Reports from both sides of the current combat show that military aircraft frequently run through several overhaul periods before being lost in action. Only those items of "quality" which have an effect primarily on appearance rather than durability should be sacrificed to speed of production. It was popularly supposed that reductions in technical performance would be permissible in war time, but experience has amply demonstrated that a small margin of superior performance is frequently a major factor in maintaining supremacy in the air. This leaves the engine builder with no alternative but to produce an engine of the maximum durability, combined with the highest degree of performance which the state of his art permits.

All engine manufacturers are enlarging the capacity of their base plants by rearranging to accommodate new machine tools and by additions to plant structure. The Pratt and Whitney aircraft-engine plant at East Hartford has been increased to several times its original size, and is an excellent illustration of expansion by the multiplication of substantially similar manufacturing process units. This procedure has some basic advantages: it does not require drastic changes in process tools; it is relatively free from the risk of the production troubles which always follow the introduction of new methods; and it utilises the established skill and experience of factory personnel without interfering with the established system of operation. It also has a major advantage, that the same step-by-step changes can be followed in the reverse order, if and when it becomes necessary to contract the volume of manufacturing operations. The separate but similar units of manufacturing capacity can be used or closed as necessary, without drastic effect on the capacity or utility of the remainder of the plant.

The Wright Aeronautical Corporation has not expanded its basic plant capacity by multiplying nearly-similar manufacturing units in the manner adopted by Messrs. Pratt and Whitney. The Wright plant has been expanded as a single-process unit by enlarging each general type of manufacturing operation and by changing the equipment to suit the larger job. This does not imply abandonment of the original equipment, because all of it can be used economically in the smaller job-lot operations which must be carried on together with the large defence programme orders in order to take care of demands for parts and obsolescent equipment. The plan for expanding facilities followed by Wright has the marked advantage that operation methods best adapted to a larger manufacturing volume can be utilised, thus saving space and man power. Such changes in manufacturing methods carry with them attendant troubles in personnel training and supervision, but the plan is sound because the current job is basically different from the engine builders' task in 1938. If acute contraction in volume of manufacturing operations follows the current expansion, the single-unit unified plant will have to be dismembered to provide material for a smaller scale of operations, as it cannot be operated in sections.

A more completely integrated manufacturing unit being built by Wright is to be operated as a subsidiary factory at Cincinnati. This is different from the two plants previously mentioned in that it is designed to fabricate only one type of engine in relatively large volume, and it is therefore laid out for line production and incorporates a maximum of mass-production methods. It is by far the largest production job yet planned in the United States for the manufacture of a single type of aircraft engine. While it is a single-purpose plant, it has been designed so that it can readily be converted to other uses.

A fourth type of expansion in capacity, for the production of aircraft engines, is being provided by licensees such as the Ford Motor Company, who are building a new plant for the manufacture of a Pratt and Whitney engine. All the engineering and production experience of the licensor is made available to the new plant, including all details of operations and tooling. This is subject to searching scrutiny by the licensee, who is free to make such changes in process as he may believe are desirable. This kind of arrangement provides a fine opportunity to utilise the methods and experience of the automotive industry in the production of a standardised aircraft engine in a modern plant designed for that specific purpose. The automotive industry is also undertaking to fabricate a large volume of parts and sub-assemblies for aircraft engines. This involves close co-operation between the two industries.

The need for practically 100 per cent. uniformity in aircraft-engine manufacture follows directly from obvious safety requirements and the incessant cry for less weight and more power output. This triangular demand provides plenty of trouble in the fabrication of propeller-drive gears. The best designs involve multiple-contact gearing and high unit loads on contact surfaces. This practice is permissible only if all parts are made with high-strength materials and hardened contact surfaces, as well as extremely uniform dimensions and surface finish. This combination excludes the use of shaving as a finishing process, forcing the use of the slower and more expensive gear-grinding. This is a typical example of the kind of problem which prevents the adoption of all mass-production methods.

A better idea of the improvements effected by the introduction of high-production machine tools and proper planning may be had by quoting actual figures. The master connecting rod of one radial engine, for example, has not been recently altered in design in any manner which might tend to simplify production; nevertheless, the production time on this part has been reduced from 32 hours to 20 hours within a year, entirely by the use of new equipment and careful operation planning, adapted to a larger production schedule. Another example of savings effected by use of line-production equipment is the case of cylinder painting. One man could paint 10 cylinders, using manually-controlled spray equipment, in the time in which 6 men now paint 200 cylinders with a semi-automatic machine, a reduction of 70 per cent. in the labour per unit. An aluminium crankcase weighing 90 lb., used in a 1,000-h.p. engine, was produced in a total time of 29 hours. It was replaced, to improve durability, by a steel crankcase, weight 125 lb., production time, 142 hours. This sacrifice in cost and weight was painful, but necessary to maintain a high standard of safety. Thanks to co-operation between designers and production men, and with help from a larger schedule, an improved type of steel crankcase for the same engine was reduced to 90·5 lb. weight, and is produced on improved tools in only 58 hours. The engine power output has also been increased by 20 per cent., a level scarcely possible with the previous material. The net result is a more durable product, and some saving in weight per unit of power output, at but a moderate increase in unit cost. It should be observed that American aircraft-engine prices (9 to 11 dols. per horse-power) are lower than those for other comparable products.

In the past year, in a period wherein actual engine production was approximately trebled, substantial reductions were made in the man hours required for the production of a group of important sub-assemblies in the Cyclone 9 engine. For this group of parts, the machining time was reduced 24 per cent., and the foundry time, 12 per cent. For similar parts of the Cyclone 14 engine, the shop time was reduced 26 per cent., and the foundry time, 10 per cent. Some of these savings may be attributed to minor simplifications in design and finish requirements, but by far the greater part is credited to careful production planning and utilisation of the latest developments in machine tools. As production increases, the lot sizes will also increase, with a corresponding reduction in set-up time. It is anticipated that an additional saving of about 5 per cent. in machine time will result. These savings were effected during a period in which 3,000 unskilled men were given a short course of training and absorbed in the shop force. When they attain a full measure of productive skill, results will naturally improve further. All these encouraging results have not been attained without paying a substantial toll in other ways. Shop scrap has increased by 25 per cent., and personnel training costs are a large sum. Other similar items make an imposing total, but the net result is that the job is being accomplished nearly as scheduled, and at a cost which can reasonably be justified by current circumstances.

* Paper entitled "New Production Lines for Aircraft Engines," presented before the American Society of Mechanical Engineers at the annual meeting in New York, December, 1940. Abridged.

MOULD AND CORE WASHES.*

By W. Y. BUCHANAN.

THE materials used in manufacture of blacking have been listed at great length elsewhere, but usually the base material is coke breeze and possibly some additions of fireclay. Where fireclay is added, it is usual, especially when subsequently mixed by hand, to make no further additions except water in the making of blackwash. The author has for a number of years used blacking made from coke only and added to the resultant blackwash such materials as bentonite, Colbond, dexterine, semi-solid core oil, coal dust of high volatile content, and even crude oil. The object of the bentonite, Colbond, dexterine and core oil was to prevent the blacking rubbing away readily after drying, although the core oil acts in a manner different from the clays. The coal dust was used with the same object in view, it being intended that at the drying temperature the volatile matter would be driven off and during the process a slight coking or crusting would take place.

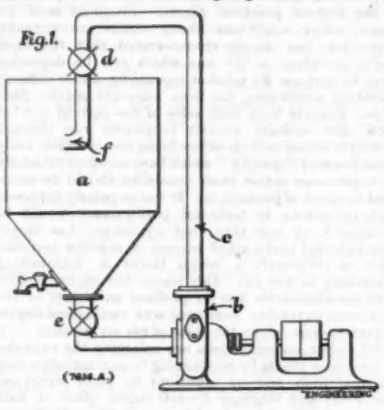
Special additions such as alkalis, intended to improve the suspension of the clays in water, were not used owing to their corrosive action on the mixing tank, but crude oil was tried because of its action on coke dust, as in the froth-flotation process. The application of this crude oil is only possible when an emulsifier is used in the mixing process, such as is described later in the paper. Coke has a specific gravity of about 1·3, is by nature very hard and abrasive towards metals even when finely ground, has a low percentage of volatile matter, high fixed carbon, and usually low ash. Blackwash consists essentially of blacking and water plus additions, varying in concentration from a thin liquid to, in some cases, a heavy mud.

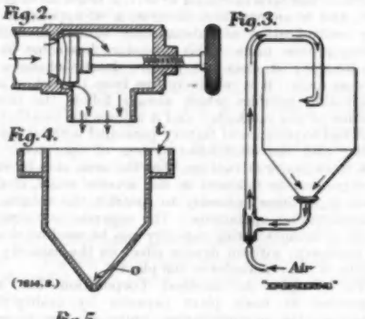
Coke dust tends to settle in water, and constant stirring becomes necessary during use. Up till recently, the usual method which has been practised without variation for generations consists of a rectangular tank or trough in which the blackwash is mixed and stirred by pushing backwards and forwards a wooden rake with a long handle and probably some holes in the blade. The dry materials are slowly added and stirred in. The moulder always stirs the liquid before removing a bucketful for use. By this means the liquid is always drawn from the top and has a tendency to concentrate as the level drops. It is, or was, the usual practice to mix this blackwash in considerable secrecy, using various personal tests, such as dipping the hand into the blackwash and observing this as it dried. Many additions were made, of course, such as clay water made from common red clay, and the preparation of the blackwash might occupy a man's time equivalent to about 8 hours a week for a foundry employing 60 coremakers and moulders on dry sand and using two mixed lots of about 50 gals. each.

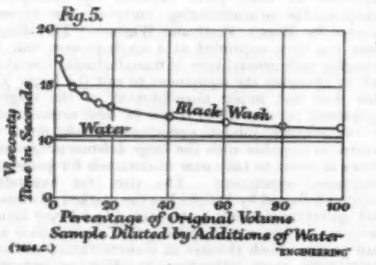
The author's experience of this problem covers a number of years, and details of methods actually tried out are included in the following notes. The first type consisted of a barrel and stirrer. Where overhead shafting is available for power drive, a barrel or circular tank is fitted with a simple type of stirrer and suitable gearing, and preferably a fast and loose pulley. Baffles are fitted to the sides of the vessel to assist mixing and prevent the liquid from swirling round bodily. A draw-off cock is provided at the bottom of the barrel or tank. This type of apparatus presents some difficulty in first obtaining a solution, as the partly-moistened materials tend to build up heavily on the baffles. With constant scraping down, the liquid becomes smooth and uniform, and, so long as the movement continues, tends to remain so; but, if allowed to settle overnight or week-end, the mass becomes solid in the bottom. Since the liquid is in this case drawn off from the bottom, the blackwash becomes thinner as the level falls.

The wet-grinder type of mixer put on the market by the British Rema Company, Limited, consisted of one or two tanks and a system of piping and valves for drawing liquid from the bottom of the tank or tanks and passing this through a wet grinder unit, then delivering it to the top of the tank. The machine was belt or motor driven. It appeared to be very suitable for materials in which a mixing and grinding action was required. The claims made for it were that it produced 40 gals. of high-grade blacking or other facing material in 15 minutes, and there can be little doubt that this output would be achieved. With the wet-grinder type in mind, the author had a plant constructed on a similar system, replacing the wet-grinder unit with a centrifugal pump of the "chokeless" type. The reason for having this machine constructed was that the materials used were ground and graded and therefore did not require further grinding.

The early trials of this machine fully justified expectations. It is illustrated diagrammatically in Fig. 1, herewith. In this diagram, *a* is a 70-gal. tank; *b*, a 2-in. chokeless pump; *c*, a 2-in. diameter tube for circulation; *d* and *e*, shut-off valves; and *f*, a right-angle bend, set near the casing to produce a swirling action. The time for filling the tank, adding the dry materials, and mixing completely was 19 minutes for 50 gals. of water, plus other materials, making in all about 60 gals. of blackwash. The action of this system seems ideal, and by keeping the delivery tube close to the side of the tank the stream of liquid round the side of the tank sets up a rapid whirlpool effect with a large vortex in the centre. The advantage of this right-angle bend and the resultant whirlpool was that dry materials, which normally float and do not wet quickly on a quiet surface, swirled round once or twice and then shot down the vortex, when they were immediately dispersed in the pump. For a considerable time no mechanical trouble was encountered. The usual practice was to mix the blackwash in the tank nearest the pump and deliver to the outer tank for storage and use, a new lot being always ready to follow the one nearly finished. Where blackwash had been unintentionally allowed to settle in the pump, or occasionally due to severe frost and lack of shop heating during winter holidays, great difficulty was encountered in starting up.







It was usual to put the machine on mixing at the beginning of the shift, and possibly after the luncheon interval, for a few minutes. As would be expected, when the mixing process was not in operation for any length of time, the small lots drawn from the tap tended to become heavy and consequently the blackwash got progressively thinner. Moulders were instructed to empty their blackwash buckets back into the tank so as to clear out the heavy cake which grows on the bottom, in the interests of economy, but unfortunately they sometimes forgot to remove the hemp swab before doing so, and this required the partial dismantling of the tubing to get the system freed again. Water was connected to the tanks for convenience, and it was soon observed that, with the plug cocks closed, water leaked quickly from one tank into the other. The wear was due to the action of the blacking between the sliding surfaces, and when this leakage developed the cocks had to be renewed.

The pump impeller, although very robust, also wore out and, of course, the efficiency dropped off considerably before complete renewal was necessary. It is possible that extremely rapid mixing might have been sacrificed in the interests of longer life and less repairs, because the pump seemed to deliver the blackwash under much more pressure than was strictly necessary. The most serious trouble from wear, however, arose from the difficulty of keeping the pump spindle packed tightly. Even with frequent renewal of the packing, the spindle became worn unevenly into grooves, and the leakage was thereafter constant in spite of frequent packing. Water tended to leak away, the mixture became concentrated and the surrounding floor was always covered with blackwash. It became obvious that the six plug cocks were a source of trouble, and that, if the pump were raised, the leakage would be reduced. If, on the other hand, the pump were eliminated altogether, the trouble would disappear.

The plug-cock type of valve is not suitable for blackwash. The action of turning off the liquid smears the blackwash into the space between the machined surfaces, thus wearing a ring clearance through which water can by-pass round the plug in the closed position. Where two tanks are connected to a pump, this leakage of water from one tank to another causes trouble in mixing. A plain type of valve, such as is used for heavy oil (Fig. 2, herewith), would be more suitable, provided it has a leather or rubber washer to ensure a tight joint when closed. If the bore at the smallest part of this valve is kept as large as possible, say, not less than 2 in., there would be little tendency for it to choke up. There is an alternative type, intended for corrosive liquids, in which a rubber tube is incorporated in the pipe line, and the valve principle simply depends on the pinching or flattening of the tube; but, without an actual trial, it is impossible to say whether its life would be any improvement on that of other valves.

During repairs and temporary breakdown intervals, compressed air was used in mixing, using a common 36-gal. wooden barrel to mix and contain the blackwash, into which was thrust an iron pipe connected to the air supply by means of a rubber hose and the usual off-on control valve. The mixing, after the primary wetting of the dry materials was achieved, was erratic, since the common tendency was to use too much air and to "boil" the blackwash out of the barrel. As this type of power is easily handled, cheaply adapted, and requires no moving parts, it was decided to adapt it to this purpose, at the same time eliminating the undesirable features.

The first idea tried, Fig. 3, herewith, was an adaptation of the injector, blowing high-pressure air from a small jet upwards from the bottom of a vertical tube having a Tee-piece branching off the bottom of the tank. By this means it was hoped to cause a circulation of liquid from the bottom of the tank up the tube to the top. This was constructed with standard 2-in. pipe fittings, and did actually operate as expected, but the system would require considerable improvement in design. The material tended to settle badly, owing to the direction of flow. Settling of the solid material to the bottom of the conical vessel, on choking, was aggravated by the suction in the same direction, but it was intended to close the top or delivery end of the tube and to divert the air pressure in the reverse direction to clear the obstruction when necessary.

The experiment with the injector system was followed by a simpler design, which consisted of a jet of air introduced at the bottom of the vessel of the same conical shape. The air line was fitted with a small screw valve with rubber valve-facings. This allowed a very low air consumption, the movement of the liquid being just sufficient to prevent continuous settling while the blackwash was being used. At the initial mixing stage, the air can be turned on so as to produce violent "boiling" if rapid mixing be desired. This system is now in continuous operation, making 60 gals. every day except Saturday.

A typical mixture in use at present is: blacking 224 lb., plumbago 12 lb., bentonite 20 lb., and water 500 lb. The tank is filled with water to measured level, the air turned on to produce a violent boil, and the dry materials added and dispersed. The whole operation of mixing takes about 35 minutes, at the end of which time there is still evidence of small lumps; but, since these are all at the top, they would present no trouble even if the blackwash were used immediately, since the liquid is drawn off from the bottom of the vessel. After 35 minutes' mixing, the air is turned down to a minimum, and presumably these few remaining small lumps become water-logged and are then dispersed in the gentle current of liquid. The quality of smoothness in the blackwash improves to its best in about two hours after mixing. There are a number

* Paper read at the 38th annual meeting of the Institute of British Foundrymen, held in Manchester on July 12, 1941. Abridged.

COMPRESSED-AIR ACTUATED PUMP.

MESSRS. AMES CROSTA MILLS AND COMPANY, LIMITED, HEYWOOD, LANCS.

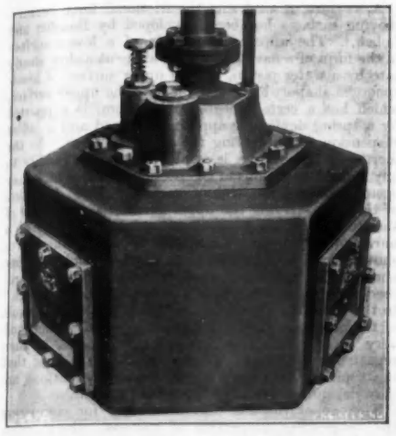
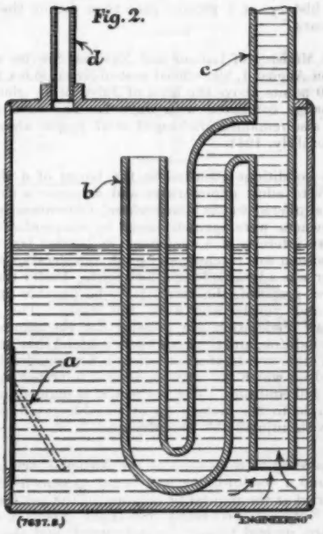


FIG. 1.



of advantages in this form of mixer. There are no working parts to wear out, and only one valve to each tank which might require replacement. The direction of flow in mixing, being upwards, automatically clears the bottom of the cone of settled solid material, and any settling material returns to the concentrated part of the current caused by the air stream. The first cost and cost of running continuously are very low. Careful measurements of the actual volume of air used in mixing were made, as well as measurements of the current consumed in producing compressed air at 90 lb. per square inch, and from these figures it was found that the cost of running at low pressure after the initial mixing stage was one penny for three hours.

Defects in mould surfaces often throw suspicion on the blackwash used and previously the blackwash mixture would be blamed or exonerated equally without evidence of any reliable kind being available. This lack of any test-method usually kept the foundryman using a certain brand of blacking exclusively, irrespective of price, and afraid to make any change. The use of controlled mechanical mixing made it easy to reproduce the exact conditions each time, and so blackings could be prepared and compared on exactly the same footing. It was thought desirable to develop some form of routine test which could be applied at a moment's notice in order to detect careless interpretation of instructions regarding weights of materials. Specific gravity is the first obvious method, and several forms of hydrometer were tried, including some specially made; but these were found very unsatisfactory, since the hydrometer usually failed to respond to very obvious changes in concentration and the reading of these instruments in blackwash is anything but accurate. The specific-gravity bottle was also used. The usual size is unsuitable and that used was of 1,000-ml. volume. To measure specific gravity by this method takes much longer than the measurement by hydrometer but, provided that it is done carefully, the figures are accurate, though extremely insensitive to heavy additions of solid material to the blackwash. This is unavoidable where these materials themselves have such a low specific gravity.

In his paper dealing with oil-sand core manufacture, Sheehan illustrated a viscometer which he had used, but did not give a detailed description. After a little trouble, however, the author obtained one which appears to be the same (Fig. 4, opposite). It consists of a brass cup with a conical bottom, a definite volume of 113 ml. and an orifice *o*, 0·146 in. in diameter. A trough *t* runs round the top so as to catch the overflow on filling completely. Its application would consist of rapid checking of any particular lot of blackwash to test for undue settling, improper mixing, or unauthorised changes in the proportions of materials. The value of such a test is more important than may appear at first sight, because the fact that an immediate check is available acts as an efficient deterrent on carelessness in measurement of materials used. The manipulation of this viscometer is simple and the results very satisfactory; for example, the triplicates of measurements made are five times out of ten exactly the same and, when variations do occur, they are of the order of 17·2, 17·0, 16·9 seconds, or 15·0, 15·0, 14·8 seconds. The time for each measurement of viscosity is about 20 seconds, whereas specific gravity by weight takes a considerable time and, although the hydrometer is as fast, the results are useless. To test the sensitivity of the test by viscometer to changes in the blackwash, a convenient sample was taken and diluted progressively with water, thus altering the percentage of solid materials. The results, expressed in the graph, Fig. 5, on the opposite page, show that small alterations of concentration affect the viscosity reading considerably. It was found that water gave a reading of 10·4 seconds and consequently, as the graph approached this figure, large additions of water would make less difference. However, at normal concentrations the viscosity test is very sensitive. Though some foundries use a much heavier blackwash than 17 seconds, it is felt that the viscometer will apply equally well to all these mixtures.

In sampling for this or any other test on blackwash it is essential, when taking the sample, to see that it represents the batch to be tested. The sample should be drawn while the liquid is actually mixing, except in cases where it may be desired to test the rate or degree of settling, when samples would be drawn at different levels as required. The procedure would be to run off at least the volume of the delivery pipe, return it to the tank, and then run off the sample. To keep the sample uniform during testing, it is best to pour it quickly from one container to the other immediately before filling the viscometer. The orifice is closed by placing the finger under it and filling the cup till it overflows into the annular trough; then, using a stop-watch, the exact time is taken from the instant of release till the small stream breaks. With blackwash there is no doubt about the end point, as the stream ceases very sharply.

In making blackwash and testing by the old method of dipping the hand into the liquid and gauging its quality by what stuck to the back of the fingers, it is doubtful what property was actually tested; if, indeed, anything was tested at all other than a rough idea of the concentration, and perhaps some idea of clay content, where this was added, measured by colour. It was thought worth while to attempt some form of rational analysis by which a sample could be resolved into its relative percentages of water, blacking and clay. This was done by first taking a known weight of blackwash and filtering off the solid material, which gave the correct proportion of water to solids. The original materials, blacking and clay, were then tested for "loss on ignition" at red heat; this loss would include water of combination and volatile matter. With this information available, the loss on ignition of the mixture of blacking and clay filtered off from the sample is obtained, and the proportions of clay and blacking found by calculation, as in the following example:—Weight of sample of blackwash = 122·64 grms. Weight of clay and blacking in sample = 45·344 grms. Therefore, 100 grms. of sample contain 37 grms. of clay and blacking. Loss on ignition on the mixture of dry clay and blacking = 82·98 per cent. Loss on ignition of Colbond = 18·05 per cent. (as received). Loss on ignition of blacking = 85·38 per cent. (as received). To find the proportions of clay and blacking: Let x = percentage of clay in the mixture, and $(100 - x)$ = percentage of blacking. Then $18{\cdot}05\,x$ = loss due to Colbond; $85{\cdot}38\,(100 - x)$ = loss due to blacking.

Now

$$\frac{18{\cdot}05\,x + 85{\cdot}38\,(100 - x)}{100} = 82{\cdot}98.$$

Hence, $x = 3{\cdot}56$ per cent. (clay in dry solids). Therefore, clay in blackwash sample = 1·32 per cent; blacking in blackwash sample = 35·68 per cent.; and water, by difference, = 63·00 per cent. After extended trial, this method of check by analysis appears to be reasonably satisfactory, and as an occasional check has been found very useful.

COMPRESSED-AIR ACTUATED PUMP.

THE pumping of water having solids in suspension is always a troublesome matter and generally involves a considerable amount of maintenance of the pump. To avoid this the moving parts of a pump intended to handle such liquids should be kept to the minimum. The compressed-air actuated pump shown in Figs. 1 and 2, on this page, has a single moving part only, namely, a plain flap valve, and thus complies with the requirement mentioned above. The pump, which is known as the "Pneu Pump," is now being manufactured by Messrs. Ames Crosta Mills and Company, Limited, Moss Iron Works, Heywood, Lancashire, whose long experience with sewage plant has made them thoroughly familiar with the problems involved in handling strongly turbid liquids. The pump, as may be inferred from the figures, is of the flooded-suction type, that is, it is lowered in the sump, well or excavation it is desired to clear and the air supply is led to it by a rigid pipe in the case of a permanent installation and by a flexible hose for temporary use. The compressed air source is, of course, at ground level. The volume and pressure of the air required naturally varies with the discharge capacity, and large deliveries and high heads are not very practicable, but as the range of sizes manufactured includes pumps delivering up to 100 gallons per minute with a head of 50 ft. most normal requirements can be dealt with.

The principles of the pump are best understood from the diagrammatic section, Fig. 2. A closed chamber has an inlet flap valve *a*, near the bottom, a syphon-like seal pipe *b* leading into the open-bottomed delivery pipe *c*, and an air-inlet pipe *d*. The pump is shown in the figure in the act of discharging, the water being driven up the delivery pipe by the compressed air in the upper part of the chamber. This action continues until the water level in both chamber and seal pipe falls to a point at which the U-bend of the seal pipe is reached. At this point a bubble of air passes the bend and continues upwards into the delivery pipe clearing the water in this pipe before it. The chamber is then in communication with the atmosphere and, as there is an unrestricted flow, the pressure in the chamber falls to virtually that of the atmosphere. Water then flows through the inlet valve and the chamber fills up, this flow ceasing as soon as the water level reaches the open end of the seal pipe which then also fills up locking the compressed air in the chamber, after which the discharge portion of the cycle recommences. The action is, therefore, automatic as long as the pump is submerged and the air supply is maintained.

The pump body may be of cast iron as in Fig. 1, or of welded steel as indicated in Fig. 2. The flap valves are attached to the body externally as in Fig. 1, so that replacement is readily effected. The air supply and delivery pipes can be clearly identified in this view. The small spring-loaded valve is a relief valve. In the larger sizes of pump, a valve can be fitted on the air pipe in order to reduce the air consumption during the filling part of the cycle. The air supply in relation to the water level in the sump or well can be simply controlled, if the compressor is motor-driven, by means of a float-operated switch. Alternatively, a simple float-operated valve can be fitted to the air pipe, the normal compressor unloading gear coming into operation when the valve is closed. For temporary use, such as clearing an excavation of water, no individual compressor is likely to be needed since, in such work, there is often a portable compressor set for running pneumatic tools and similar purposes.

CONTROL OF PIG IRON IN CANADA.—With the object of conserving iron and steel for essential war industries, all orders on the books of producers of pig iron in Canada were cancelled as from June 9, in accordance with instructions issued by Mr. H. D. Scully, Steel Controller of the Department of Munitions and Supply. A statistical summary of production and consumption is being prepared and, meanwhile, all new orders for pig iron are being forwarded to the Steel Controller for approval.

LABOUR NOTES.

Addressing the annual conference of the Transport and General Workers' Union at Llandudno last week, Mr. Bevin, the Minister of Labour and National Service, said that he refused to be a party to the stabilisation of wages until the price policy was settled. The difference in the position now was that the Government had decided to stabilise prices. Experience had shown that wages followed prices, but a long way behind them. The Government was considering a fairly wide development of rationing, not merely with the object of controlling prices, but in order to achieve a correct distribution. That was vital. The trade union movement had asked for stabilisation and the Government had undertaken to give it.

The conference adopted a resolution calling upon the executive to take the initiative in pressing wage claims designed to "catch up" with the cost of living. It also re-affirmed the adherence of the union to the principle of the rate for the job which now rules in a considerable number of industries, and instructed the council to demand its recognition by the Government and local authorities. Apart from representing only elementary justice to women doing the same work as men, equal pay for equal work was, it was stated, vital as a means of safeguarding the standards established for men through years of struggle by the trade unions.

A resolution submitted by Mr. Deakin, the acting general secretary of the union, and adopted by the conference called for the nationalisation of all forms of transport at the earliest possible moment. Dealing especially with the case of road transport, Mr. Deakin said that passenger services had improved, through better organisation, during the last ten years, but they would be much more efficient under national ownership. The Minister of War Transport was considering plans for the partial control of road goods haulage on the basis of hiring vehicles from owners and carrying on the services. But, in Mr. Deakin's opinion, the proposed arrangement would not solve the problem. The profit motive must, he declared, be eliminated.

Discussing the subject of the stabilisation of wages, the writer of the editorial notes in the August issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation, expresses the opinion that "the Government has wisely refused to embark on something that will simply impede the war effort to an extent impossible to imagine, and which in the end would be bound to fail because of the inherent practical difficulties involved in the application of any such proposal." He denies that wage earners are "reaping a harvest entirely unrelated to the extra effort and time put in to earn it." "Apart from what they are able to earn by overtime or increased effort, the flat rate war bonuses that have been obtained in practically all of the major industries are entirely inadequate," he claims, "to meet the increased cost of living, in spite of what the index says. Any housewife," he writes, "can prove this."

Continuing, *Man and Metal's* contributor says:—"In many important trades, including that of engineering, a weekly bonus of 8*s.* 6*d.* is all that has been obtained, and, indeed, is becoming the standard for the present index figure of 100. Anything earned above this is due entirely to overtime or increased output. If stabilisation is to affect any part of the wages apart from the flat-rate war bonus—which represents, after all, a very small part of the weekly earnings—it can only be done by limiting the payment for overtime or cutting rates when output is increased. Only a fool would attempt that and expect, at the same time, to retain national unity, industrial harmony, or even the present levels of output. It is as sure a way of losing the war as any we know of."

The report which the General Council have prepared for submission to next week's Trades Union Congress at Edinburgh deals with, amongst other things, the discussions which have taken place with the Chancellor of the Exchequer and the Minister of Labour and National Service on the contents of the Government's White Paper. The Council, it is stated, registered strong opposition to any attempt to interfere with the system of free negotiation on wages, and it promises to watch arbitration proceedings and negotiations for any evidence that decisions are influenced by the Government's pronouncements. If there was evidence of such influence the attitude of the trade unions to arbitration machinery would, as Sir Walter Citrine had indicated, have to be reviewed.

The unions affiliated to the Trades Union Congress had a total membership, at the end of last year, of 5,079,094—an increase of 212,383 as compared with the position at December, 1939. It is still steadily rising. "It is not only in numbers that the Trade Union Movement is growing," the General Council say in their report. "Its prestige and the general acceptance of its representative capacity have never increased, in its history, at a greater pace than during the past two years."

The Ministry of Labour and National Service states that on August 1, the official cost-of-living index figure was 99 points above the level of July, 1914. Showing no change compared with July 1. The food index figure also remained unchanged at 67 points above the level of July, 1914.

The conditions attached to the bonus of a shilling a shift to adult mineworkers and sixpence a shift to youths, offered to the Mineworkers' Federation by the coal-owners, were again discussed by representatives of the two interests at a conference in London last week. No decision was reached, and joint consideration of the matter was adjourned for a fortnight. Under the coal owners' proposal, the bonus is to be payable only to men and youths who work full weeks. The Mineworkers' Federation are pressing for the removal of that condition, and the coalowners contend that without it—in other words, if absenteeism is not penalised—the difficulties which the wage increase is intended to overcome will continue. The workers, it is understood, are agreeable to the setting up of suitable machinery to deal with unjustifiable absenteeism.

According to a decision of the National Arbitration Tribunal a cost-of-living war bonus agreement cannot be varied at the request of only one of the parties to it. The National Federated Electrical Association, it appears, desired to vary its agreement, and the other party dissented. The difference was referred to the National Arbitration Tribunal which ruled that the Association could not vary the agreement. In its award, the Tribunal stated that it deprecated the making of an agreement for a bonus to operate for the war period which contained no provision for its review. Until such agreements were abrogated by legislation. This could only be varied or dissolved by the consent of both parties.

The eighteenth report of the Select Committee on National Expenditure gives the replies of some of the Ministries to criticisms of their operations. The Ministry of Supply is recorded as admitting that excessive overtime does not pay. It was not, it was explained, conducive to efficiency, economy or the well-being of the workpeople. Labour, however, was not always available for the three-shift system which the Committee suggested as an alternative, and the Ministry did not agree with the Select Committee's proposal that working hours should be fixed by the Ministry of Labour and National Service.

According to the Select Committee men engaged on ship repairs do not appear to work with the same eagerness on jobs of low priority. The local officer of an un-named trade union is blamed for tactics that cause delays. It is alleged that he only permits overtime if exceptionally high rates are conceded, and that he fines men who work overtime without his permission. He, also, it is added, resists the use of pneumatic riveters. The Select Committee recommends that the official's activities should be made to conform with constitutionally negotiated agreements. There are district delegates in most unions who avowedly are political extremists, but it is inconceivable that, in this instance, the official acted without the authority of his District Committee if he did really do what the Select Committee says he did.

The International Labour Office's *Review* states that a Legislative Decree adopted in the Protectorate of Bohemia-Moravia on March 6, and promulgated on April 9, provides for a reduction in the period of apprenticeship for apprentices called to the colours. Under section 98 (*a*) paragraph 2 of the Czechoslovak Industrial and Handicrafts Code, a period of apprenticeship may not be less than two years or more than four years. Within these limits, it is fixed by the rules of the guild concerned or by the contract of apprenticeship.

The new Legislative Decree provides that if an apprentice is called up for military service, his apprenticeship is deemed to have been terminated if he has completed at least three years of the period of apprenticeship in cases where the period is fixed at four years, or if the period still to run at the date of calling up is not more than six months in the case of an apprenticeship for a period of less than four years. In neither case may the period of apprenticeship be less than two years.

TEMPERATURE AND THE LUBRICATING PROPERTIES OF GREASES.*

By Dr. D. Tabor.

A method of analysing the frictional force between moving surfaces has been developed by Bowden and Leben.† The apparatus consists of a lower surface in the form of a flat plate driven along at a slow steady rate by a water piston, and an upper surface of hemispherical shape which rests on it. The upper surface, which has a certain degree of freedom, is supported by a spring device for applying the load and a bifilar suspension for measuring the frictional force. As the inertia of this system is small, it responds readily to any rapid fluctuations in the frictional force which may occur between the sliding surfaces. The deflection of the arm carrying the upper surface is a measure of the frictional force, and this is recorded optically on a moving-film camera. Using this apparatus they have shown that, when clean steel surfaces slide on one another, the motion may not be smooth but may proceed in a series of jerks. The top surface "sticks" to the bottom one and moves with it until, as a result of the gradually increasing pull, there is a sudden and very rapid slip. This "stick-slip" process is then repeated indefinitely. Further work has shown that the type of sliding and the frictional fluctuations are very dependent upon the nature of the metals.

This apparatus has also been used for comparing the lubricating properties of various substances on metal surfaces.‡ With the high loads (400 to 5,000 gm.) and the low speeds employed (0·001 cm. to 1 cm. per second), the conditions correspond to boundary lubrication. It is found that, with mineral oils, the motion still proceeds by a series of "stick-slips," and the general behaviour is similar to that of unlubricated surfaces, except that the length of the slips is different and the average value of the friction is lower. Certain substances are, however, able to prevent "stick-slip" and to change the motion to continuous sliding. This is true, for example, of the long-chain fatty acids. The addition of small quantities of these substances to a mineral oil will have a similar effect and will cause continuous sliding. The change in the frictional behaviour is accompanied by a decrease in the wear of the sliding surfaces.

This change has also been used to detect the oxidation of a non-polar mineral oil when it is heated in air.§ The original oil gave "stick-slip"; after it had been heated for some time in the presence of air, the motion changed to continuous sliding and, at the same time, the track showed less wear. The experiments show that this is due to the formation in the oil of oxidation products which contain polar groups. These compounds are adsorbed on the surface and improve the lubrication. The rate of formation of these compounds becomes appreciable in most oils at temperatures above 150 deg. C. As would be expected, the change in frictional behaviour is irreversible, and on subsequent cooling the sliding persists.

If a lubricating oil already contains suitable polar bodies it will, of course, give smooth sliding without heating or oxidation. Some recent experiments‖ on oils of this type have revealed a new effect. As the surface is warmed up, "stick-slips" set in. This may occur at quite a low temperature, *e.g.*, 50 deg. C. The "stick-slips" increase in size as the temperature is increased, and decrease as the temperature is reduced. Provided the heating has not been sufficiently prolonged to cause appreciable oxidation of the lubricant, the effect is reversible. Similar effects have also been observed with pure fatty acids and alcohols. Subsidiary tests have shown that this is not due to any change of viscosity with temperature, but is to be attributed to a desorption or disorientation of the adsorbed lubricant film.

In some cases, the temperature at which this disorientation or surface melting of the adsorbed film takes place corresponds to the bulk melting point of the substance; in others, *e.g.*, fatty acids, it is considerably higher. Apart from its theoretical interest, this effect is of considerable practical importance. A lubricant which behaves well and gives smooth sliding at room temperature may have poor lubricating properties when the metal surfaces are warm. With numerous lubricants the temperature at which this transition occurs is well below 100 deg. C., and so is readily attained by many of the moving parts of a running engine. The temperature of the transition is a measure of the strength with which the lubricant

* "The Influence of Temperature on the Lubricating Properties of Some Greases." Reprinted from the *Journal* of the Council for Scientific and Industrial Research, Australia, vol. 14, No. 2 (1941).

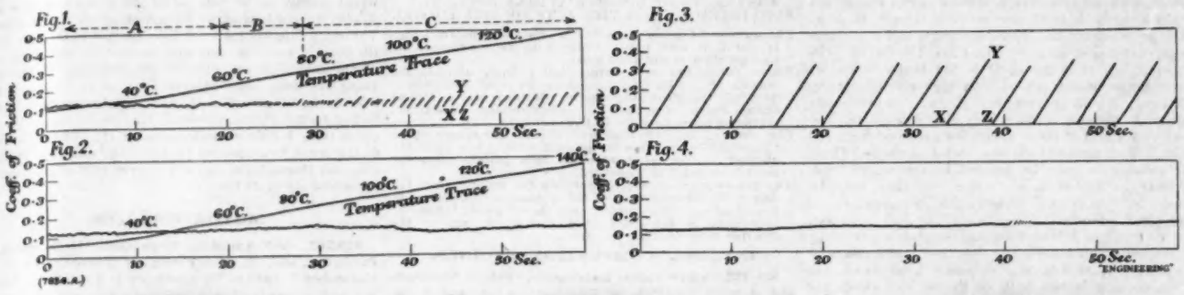
† *Proc. Roy. Soc. A.*, vol. 169, page 371 (1939).

‡ *Phil. Trans. A.*, vol. 239, page 1 (1940).

§ *Trans. Faraday Soc.*, vol. 35, page 900 (1939).

‖ *Nature*, vol. 145, page 308 (1940).

TEMPERATURE AND LUBRICATING PROPERTIES OF GREASES.



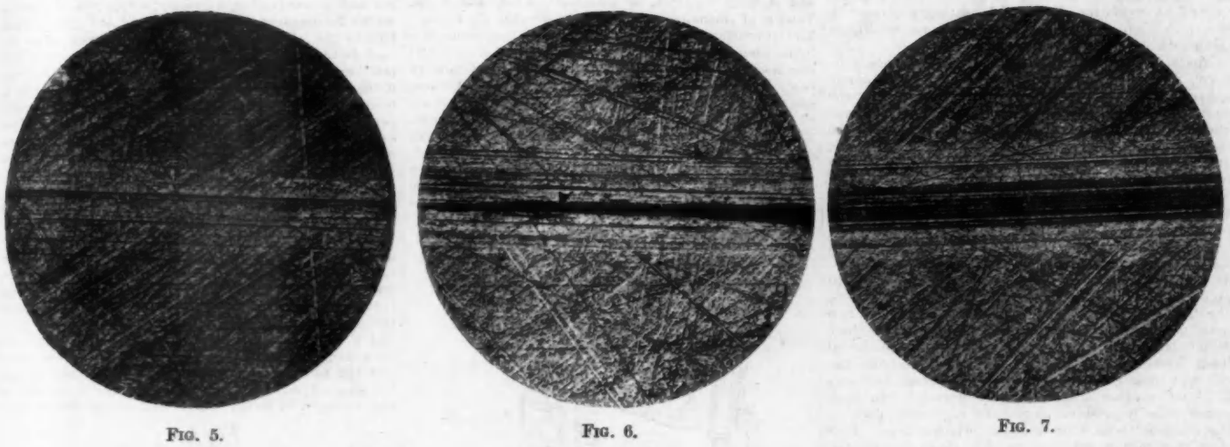


FIG. 5. FIG. 6. FIG. 7.

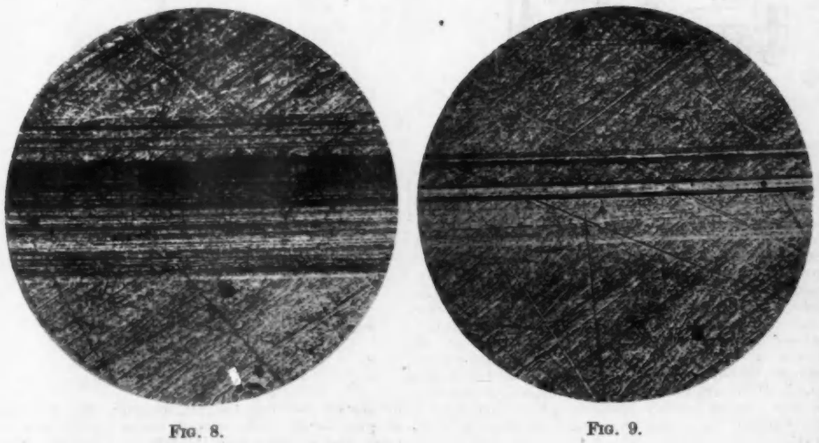


FIG. 8. FIG. 9.

film adheres to the surface. The higher the temperature, the stronger the adsorption. It is possible to compare different lubricants in this respect.

It is clear that, if a commercial lubricant is to be used at a higher temperature, its lubricating properties should be determined at that temperature. Measurements have been carried out at different temperatures on some commercial lubricants, and some typical results which illustrate the general behaviour are given here. We may take for example two commercial greases P and Q. Both consist of a mineral oil which contains about 5 per cent. of aluminium stearate. The main difference between the greases was in the type of mineral oil used. In grease P, the oil was a Pennsylvanian Bright Stock which is very stable to oxidation. In grease Q, the oil was a Californian Cylinder Stock which is not so stable to oxidation. A grease was required for lubricating hot steel surfaces, and experiments were carried out to determine which was the more suitable.

The frictional changes which occur when the lubricated surfaces are heated are shown in Figs. 1 to 4, herewith. Fig. 1 shows the behaviour of grease P, on heating to 150 deg. C. It will be seen that smooth sliding occurs at room temperature and the coefficient of friction is about $\mu = 0{\cdot}12$. This smooth sliding persists up to a temperature of about 70 deg. C. (portion A). At this temperature "stick-slips" set in and increase in size as the temperature is raised to 150 deg. C. At 200 deg. C. (see Fig. 3) the stick-slips are very marked.

In these traces the passage of time is from left to right. The deflection of the arm carrying the upper surface (which measures the tangential force between the surfaces) is recorded at right angles to this direction. This tangential force divided by the load gives the coefficient of friction, and the value of this is marked on the ordinates. The heavy trace therefore represents the variation of friction with time. It is seen that the force opposing motion may not be constant, but may fluctuate violently during sliding. These fluctuations consist of a period X Y during which the tangential force is increasing steadily, followed by a very rapid fall Y Z. Subsidiary experiments show that the slope of the line X Y implies that the upper surface is moving forward with a velocity identical with that of the lower surface, and it is clear that the two surfaces are sticking together. The upper surface is being carried forward by the lower one, and no relative motion is occurring. Suddenly, at the point Y, a rapid slip of the upper surface occurs. When the frictional force has fallen to Z, the surfaces stick together again. The process is then repeated indefinitely.

Fig. 2 shows the behaviour of grease Q on heating to 150 deg. C. At room temperature the behaviour is similar to that of grease P. Smooth sliding occurs and the coefficient of friction is about $\mu = 0{\cdot}12$. At higher temperatures, however, the behaviour is different. It will be seen that with this grease there is little change in the frictional behaviour as the temperature is raised; smooth sliding persists up to a temperature of 150 deg. C. At still higher temperatures, 200 deg. C., however, "stick-slips" set in and the behaviour more nearly resembles that of grease P, the friction trace of which, on heating to 200 deg. C., is shown in Fig. 3. With both greases the effect is reversible, and on cooling down the motion reverts to continuous sliding. Fig. 4 shows the behaviour of grease P after it has been cooled down from 200 deg. C. to room temperature.

Experiments show that the frictional changes are accompanied by a corresponding change in the wear of the steel surfaces. This is illustrated by Figs. 5 to 9, from a series of photographs of the track formed on the lower flat surface when the top slider has passed over it once. These measurements were made with the grease P. Fig. 5 shows the track initially formed on the steel at room temperature. It corresponds to the frictional behaviour of portion A in Fig. 1. It will be seen that, while the motion is smooth, the track is faint and comparatively little wear has occurred. Fig. 6 shows the track in the region where the motion is changing from smooth sliding to "stick-slip," *i.e.*, to portion B of Fig. 1, at a temperature of about 70 deg. C. It will be seen that when the motion changes to stick-slip it is accompanied by a considerable increase in the wear of the surfaces. This is even more marked in Fig. 8, which shows the track at 200 deg. C. when large stick-slips are taking place. Fig. 7 shows the track between 120 deg. and 150 deg. C., *i.e.*, over the portion C of Fig. 1. When the surfaces cool down to room temperature and the motion reverts to smooth sliding, the track again becomes fainter and shows reduced wear (see Fig. 9). A similar correspondence between the nature of the sliding and the extent of the wear was observed with the grease Q. The change from smooth sliding to stick-slip was again accompanied by an increase in the wear and damage of the surfaces.

Measurements of this type enable a comparison to

be made of the lubricating properties of different oils or greases. In this case, for example, the results show that for the lubrication of steel surfaces at room temperature both greases give a similar performance and there may be little to choose between them. If, however, it is necessary to lubricate warmer metal surfaces at temperatures of from 70 deg. C. to 150 deg. C., the results suggest that grease Q is the better, since its lubricating properties persist to a higher temperature. At 200 deg. C. both greases break down. As previously mentioned, smooth sliding may be caused by the presence of a film of polar molecules adsorbed from the lubricant and oriented on the metal surface. These polar substances may be present in the original oil, they may be added as a "dope," or they may be formed by oxidation. When the temperature is raised these adsorbed films "melt" or are desorbed. It is clear that, if the lubricant contains a variety of these polar substances, the desorbed molecules may be replaced by others of a different kind which are already present in the bulk of the oil, or which are formed by oxidation during the heating process. In this case, continuous sliding may persist to higher temperatures.

Apart from the effects discussed above it should be borne in mind that protracted heating, particularly above 200 deg. C., will cause further changes in the compounds produced in the lubricants. The resultant effect of these compounds will not necessarily be beneficial. Their harmful properties of polymerisation, gumming, corrosion, etc., may outweigh any other improvements in lubricating properties. Previous work (Bowden, Leben, and Tabor) has indeed shown that, at temperatures near 300 deg. C., the compounds produced may cause increased friction and wear.

These observations have an important bearing on the testing and comparison of lubricating substances. When, for example, a commercial "dope" is added to an oil and the lubricant tested at various temperatures, the frictional changes occurring may depend on two main factors: the temperature-desorption of the dope (reversible), and the formation of compounds in the oil itself (irreversible). As has been indicated above, the effect of these compounds may at some stage be beneficial, at another stage definitely harmful. In both cases these by-products may have a greater effect on the frictional behaviour than the original dope. It is clear that in any practical problem these complicated processes may have a critical effect on the behaviour of the lubricating substance, so that in the assessment and comparison of lubricants the actual running conditions must be fully considered.

LARGE "SILENTBLOC" FLEXIBLE BEARING.

An interesting instance of mechanical development arising from war conditions but possessing great potentialities for peace-time applications is afforded by the production of a large Silentbloc flexible bearing for certain work connected with armaments. This bearing should be of great utility in those heavy machines which, hitherto, have had to meet oscillating movements by metallic pivots requiring lubrication. The new bearing, since it has a bore of 6 in., and an outside diameter of 10 in., is a big advance on previous standard practice, the largest bearing of the standard range having a bore of 3½ in. and an external diameter of 5½ in. The length of the new bearing is 3 in., as against the 11 in. of the standard bearing. This high ratio of outside diameter to length provides greatly increased flexibility with respect to angular axial displacement, while its resistance to lateral or end displacement is adequate.

The new flexible bearing is manufactured by Messrs. Silentbloc, Limited, Victoria-gardens, Ladbroke-road, Notting Hill Gate, London, W.11, and retains the characteristics of the standard types, namely, self-alignment after deflection, and complete resistance to water, weather or grit. These ensure a long life without adjustment or lubrication. The rubber ring between the outer and inner sleeves, as in the smaller bearings, is forced into position so that the effort made by the ring to regain its original shape exerts a radial compressive force of sufficient intensity to prevent slip between the three elements provided that the amplitude of oscillation does not exceed about 20 deg. on each side of the neutral position. Increase in the amplitude on one side, may, however, cause the rubber to slip and take up a new neutral position. There is thus no likelihood of the rubber being ruptured. The smallest listed Silentbloc bearing has a bore of $\frac{1}{16}$ in., an outside diameter of $\frac{7}{16}$ in., and a length of $\frac{1}{4}$ in., and between this and the new large bearing there are obviously great differences in assembly and handling. The standard technique, in consequence, needed considerable revision, but the new methods have enabled a satisfactory rate of output to be maintained.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

INTERNAL-COMBUSTION ENGINES.

535,323. Valve-Rocker Lubrication. Pobjoy Airmotors and Aircraft, Limited, of Rochester, Kent, and C. O. Towler, of Rochester. (2 *Figs.*) November 22, 1939.—The invention is an arrangement for improving the lubrication of the rockers of the lower cylinders of radial engines. The rocker chamber 12 and push-rod tube 19 contain oil, which, in the case of the upper cylinders, can return by gravity. In order to provide for circulation of the oil in the rocker chambers of the lower cylinders, the rocker covers are fitted with pumps. In the rocker cover is a cavity 21, which serves as a pump chamber. The cavity has a valve-controlled outlet 24 and a pump plunger 25 (Fig. 2). The plunger is in the form of a cylindrical shell, closed at one end, which is

Fig.1.

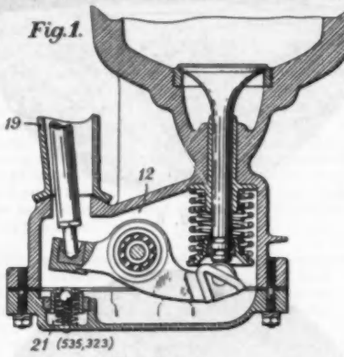
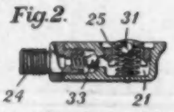


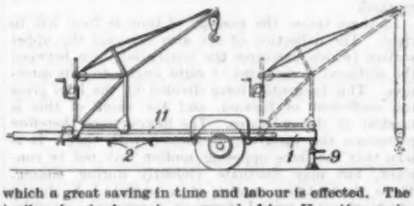
Fig.2.



normally held by a coil spring so that a flange at its open end abuts against a seating to cut off the cavity 21 from the rocker chamber 12. Through the closed end of the plunger is drilled a port, which is normally closed by a ball valve 31. The outlet 24 from the cavity is normally closed by a second ball valve 33. When the push rod operates the rocker, the end of the latter makes contact with the plunger 25, depressing it against its spring and forcing oil out of the cavity through the outlet 24 to the sump. On the return stroke of the plunger, oil is drawn from the rocker chamber 12 into the cavity 21 through the valve 31. The plunger 25 therefore acts as a return pump to maintain a continuous flow of oil through the rocker chamber. (*Accepted April* 4, 1941.)

LIFTING AND HAULING APPLIANCES.

535,357. Salvage of Aircraft. Scammell Lorries, Limited, of Watford West, and O. D. North, of Hunton Bridge, and P. G. Hugh, of Watford West. (3 *Figs.*) December 29, 1939.—The invention is a trailer or a self-propelled lorry for salvaging crashed aircraft, by



which a great saving in time and labour is effected. The trailer chassis shown is composed of two H-section main frame members 1 sufficiently long to accommodate a large portion of an aircraft fuselage. These two H-section members are spanned by channel-section cross-members 2, which support two outrigger boards for taking the landing wheel or other parts of the recovered aircraft. A pair of jacks 9 are permanently attached to the rear ends of the frame and can be swung up close to the trailer when not in use, these jacks enabling the road-wheel springs to be relieved of the abnormal loads and strains during loading of an aeroplane on to the vehicle. The main longitudinals act as a pair of guide rails for a jib crane, which is normally carried at the front end of the trailer frame, but can be traversed to the rear along the two longitudinals 1 so as to overhang the load to be lifted. The aircraft remains coupled to the lifting tackle during transit. The traversing of the jib crane is by a pair of endless chains 11. The framework of the crane is shaped so that the tail end of a fuselage can pass through the frame and over part of the tractor. (*Accepted April* 7, 1941.)

MOTOR VEHICLES.

536,263. Self-Adjusting Suspension. H. O. Henry, of Portheawl, and T. McL. Young, of Nairobi. (12 *Figs.*) November 7, 1939.—The invention is a combined damping and spring-tension adjusting device which is automatically operated by movements of the chassis relative to the wheels so as to raise the chassis when the load is increased, and to lower the chassis to a new position in which the mean chassis height is again restored if the load is decreased. Each coil suspension spring is housed within a pair of telescopic tubes 2, 3, mounted between the chassis and the wheel. The lower end of the upper and inner of a pair of tubes is increased in external diameter to form a short collar constituting an annular piston 15 which is a sliding fit within the lower end of the lower tube, the internal diameter of which is correspondingly enlarged at B. The bore of a boss 51 integral with the outer tube communicates with the chamber surrounding the upper tube above the annular piston. An intermediate portion of the bore is recessed eccentrically, two equal crescent-shaped recesses 54 being formed, one on each side of a longitudinal fillet. Within the bore is inserted a sleeve 11 which extends above the tops of the crescent-shaped recesses, and carries at its lower end a stepped cylindrical valve 24. Ports, closed by inward-opening spring flap valves, connect the sleeve and the recesses, and other ports in the bore housing the stepped valve communicate with the lower ends of the recesses. Further ports and ducts afford com-

Fig.1.

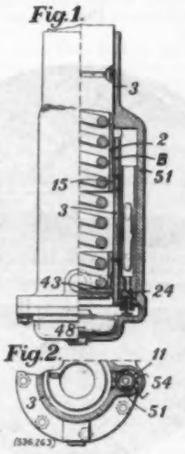


Fig.2.

munication between the oil reservoir, the pumping chamber B above the annular piston 15, the stepped valve, and a chamber in the bottom cover plate containing a flexible air-sac 48. This chamber is bounded at the top by a short inverted piston 43 which is a sliding fit within the lower end of the tube 3 and constitutes the lower abutment of the spring. In the neutral position of the suspension, the annular piston 15 covers a pair of ports which communicate with the oil reservoir. Assuming that the suspension spring has already been correctly tensioned beforehand, any oscillation which is set up consequent upon the motion of the vehicle over the road surface will cause the annular piston to travel equally above and below the ports at the neutral position and as much oil is allowed to pass back into the reservoir below the piston as is sucked out by it into the pumping chamber B. The effect is thus one of pure damping. When the vehicle is loaded, the annular piston sinks, and the ports at the neutral position are more frequently opened to the pumping chamber. Oil is thus forced down the sleeve to open the valve 24, and thence into the air sac chamber beneath the abutment piston 43. Thus the latter is gradually raised to compress the suspension spring and so return the annular piston 15 to its neutral position. The reverse operation occurs on removing some of the load on the vehicle. The suspension is thus entirely automatically self-adjusting. (*Accepted May* 8, 1941.)